NUCLEAR ENGINEERING VOL. 6 NO. 66 NOVEMBER, 1961

European Review

IN spite of the small number of megawatts now forecast as being the requirement for nuclear capacity on the continent of Europe over the next decade, there would seem to be little gloom within either the national development organizations or the industry, although there is still a great deal of frustration. This stems partly from the decrease in demand, which has caused the utility organizations, particularly, to hesitate over extensive investment at this state of the technology, but also to a large extent from the absence of clear legal rulings covering liability for accidents, legal levels of radiation and so on in a number of countries. In most areas, now, adequate legislation is through or nears finalization, but in countries such as Germany and Italy the struggle between State and private ownership is still a complicating factor. From the long-term point of view one might expect that evolution would work always towards the nationalization of essential supplies such as electricity as has already happened in France and England but it would seem necessary at this stage to create conditions, both nationally and internationally, for the two political approaches to work together and allow long-term economic forces to settle the issues. This is an aspect of power production which one might have seen the Council of Ministers of the Common Market consider, as the industrial effects are bound to be felt across the national borders, but at this early stage of European integration it is perhaps asking too much that such a controversial issue be brought to the round table.

Projects on the Continent have not escaped the wave of technical problems that have made the realization of most reactor systems more difficult and more expensive than at one time was hoped. This has caused the less-well-endowed countries to reconsider their research and development programmes and for the economic aspects to assume greater importance *vis-à-vis* scientific curiosity. At the same time, the advantages of international collaboration are more firmly acknowledged and there is perhaps a less nationalistic attitude towards at least the longer-term research and development, and also towards those projects which have not gone 100% smoothly.

Euratom

Against this background Euratom has been able to marshal its forces, determine its objectives, and establish its compromises between State and industrial interests in a way that might not have been possible if the bandwagon had continued to run. Euratom's technical record is still not impressive and there are a number of important projects under way in the Messina countries which are exclusive to the national atomic energy authority or to individual companies within the country. Even Euratom's legislative efforts have not been as comprehensive as they might have been and, for example, the completion of the State Intervention provisions has taken long enough considering it was sitting on the shoulders of the ENEA Convention.

Nevertheless, in the past year important changes have taken place in the status of Euratom which finally confirm its central position in Europe today. The first of these is the opening of the Ispra research establishment (to be followed by others) and the general build-up of the research programme, not only at Euratom's own establishments but through its system of development contracts. The fast reactor project of the CEA is even becoming a Euratom venture; the U.S./Euratom joint research programme too is gathering momentum, far less impeded by the necessity for development projects to be associated with reactor construction than might at first sight have been supposed. Although the contracts so far concluded in this enterprise do relate to the water reactors they are principally concerned with the fuel cycle and therefore are of far more general application. The second important step Euratom has taken is the launching of its own reactor development project, viz: Orgel. Previously Euratom had been content to assist existing projects in the member states and avoided having to make too critical a technical evaluation. Orgel is, however, a Euratom proposition, chosen as much for its political value (there was no existing organic heavy water project in the Six) as its technical—a feature which at this stage, perhaps, strengthens the project rather than weakens it. Euratom will have to watch, however, that its own baby does not become a spoilt child; one of the major strengths of Euratom in the past has been its openness and dispassionate attitude towards projects, a refreshing change from the pseudo-technical salesmanship with which we have all become familiar. The third important step is the decision to assist financially in the construction of power stations.

It should not be thought that the changes in Euratom's policy are of a temporary nature. They express quite clearly Euratom's determination to be a spearhead in all aspects of the commercial exploitation of atomic energy. There is to be no neglecting the immediately commercially valuable and concentrating on the long-term academic. Euratom is determined to be in the forefront of the current as well as the distant problems. This policy has been evolved in spite of quite strong opposition from its most powerful member, France.

ENEA and IAEA

It is this aspect which finally makes Euratom quite distinct from other international organizations, such as the ENEA and the IAEA. Mr. Sterling Cole in a retiring speech from the IAEA made a somewhat querulous complaint about the small splinter international organizations undermining the authority of the world group, but the world is not ready for general collaboration as the latest comic opera performances at the IAEA's General Session have demonstrated only too well.

Whatever the future of the IAEA one can see the ENEA continuing to exist so long as its projects are alive. Its

present record is impressive, highlighted by the smallness of the secretariat staff—in fact probably smaller than desirable particularly in the lower grades. The Agency has been fortunate in taking on at least two vitally interesting projects but must as well take a great deal of the credit for breathing new life into Dragon and then the Halden projects. Should the decision be taken for a ship to be built (it will be the spring before everyone is sure) then the EFTA countries who participate will need to be quite certain that this project is not to be absorbed at some stage into Euratom or die at a critical stage. It is important also to note that the drive here comes not from the reactor people but from the shipbuilders, which introduces a new dimension into international collaboration and may lead to a further extension. The Agency may also have a long-term future as the convenient vehicle for the uncommitted European countries to collaborate with the Common Market and it may also presage closer collaboration with the U.S. and Canada.

U.K. and Euratom

The assumption we are making is that the U.K. will become a member of the Common Market. Whatever the problems are, over agriculture and the Commonwealth, the recent party conferences held in the U.K. have shown clearly the attitude of the politicians (the Liberals passionate about joining, the Tories determined that the negotiations should be a success, and the Socialists trying to find ways of being in opposition whilst still expressing approval). On this side of the Channel then the wish seems clear, but there is of course the other side; will in fact Britain be welcomed? And more particularly as a member of Euratom.

From our own survey it would seem that although the reasons may differ from country to country or even establishment to establishment the U.K. would be a most welcome addition to the Euratom group. For example, France sees the U.K. as a second organization able to make a contribution as significant as her own; Germany sees the U.K. as a force able to stand up to France and limit French domination; the smaller countries see Britain as a convenient go-between for France and Germany whose relations are sometimes rather strained. Euratom itself will welcome the U.K. as they see it as a method of increasing their own competence by a very considerable amount.

There are those who believe that the absorption of Britain into Euratom can be accomplished without hardly any changes at all. They argue that the CEA with its private disproportionate strength continues to operate much as before the union, and there is no reason why the U.K.AEA cannot be accepted in the same way. Such a form of integration would, we believe, be unstable and certainly ineffective. Furthermore the taxpayers in the U.K. as well as the taxpayers on the Continent have a right to expect such integrations to make savings, not simply for Euratom to be a growing additional expense on existing atomic energy budgets. Either then the contribution to Euratom must be negligible or the strength of Euratom must continue to increase and the purely national development programmes run down. (We think here solely of the civil work.) The AEA is probably more ripe for such a change than is the CEA as this could be an excellent opportunity for yet another reorganization of its reactor development section, which, this time, could be something more than a change in titles. Only a strengthened Euratom and weakened national bodies assist in the overall political integration and we believe that Euratom will make sure this point is appreciated and will be able to make it, in effect, a vote of confidence in the whole political concept.

And rightly so. If indeed, integration is not to be followed by a pooling of resources and a strengthening of the supranational bodies then the principle of integration is wrong and we have all been working on the wrong tack. There is naturally a great deal of concern over the size of the unit and the risk that like the national development bodies, growth will be largely independent of output. There will, however, remain some form of purely national organization able (and probably anxious) to criticize and point out deficiencies whereas these independent, competent bodies do not exist at the moment. Also, there should be an industry continually taking over the profitable projects and ensuring that supranational manufacturing organizations do not appear before their time.

Continental Industry

On the industrial front the companies on the continent of Europe are, in the main, already geared to integration if they are within the Six, or, if they are within the EFTA countries, to an independent existence. Appreciating the need for representative bodies able to talk at the same level and from comparable strength with national and international political organizations Continental industry has organized forums and associations which are plotting the course of developments hand in hand with the governmental bodies. They are consciously preparing also for what is still expected to be an enormous rush of business in the atomic energy field in the 1970s.

U.K. Industry Lagging

But what of industry in the United Kingdom? The consortia become more and more expert at constructing the British version of the gas-cooled graphite-moderated reactor but have no part in the development of any other system. Only a small section of industry dealing with instrumentation and special handling equipment has an international appeal. And so it will go on. The majority of the industry, including the component companies of the consortia, sit back without any voice either in U.K. or international affairs. Their only reaction to the enormous political changes taking place is to become, if anything, more ostrich-like; after 12 months of active negotiation over a British industrial atomic energy forum the project is probably deader today than it was a year ago. Beautifully constitutional, and quite contrary to the wishes of many individuals—we venture to say most—whose opinions should be respected, the established Societies have quietly killed the idea. Unless this decision is reversed, there will be no industrial body able to prevent such repetitions of commercial tragedy as the omission of the U.K. from the Eurochemic project (which may keep British industry out of the fuel-processing business for all time in Europe).

This is merely one instance of commercial interests being neglected—they were probably never even considered—but there are many incidents in the past which might be quoted. Nevertheless while the relations between the U.K.AEA and industry remained a primarily domestic problem it could be argued that the machinery did exist but was not well used. This is only remotely true in regard to the consortia who by no means constitute the totality of the British nuclear industry. Now that the question is no longer merely domestic, a powerful competent forum is essential, otherwise the industry will have little say in its own destiny. But if matters are allowed to drift then the industry must not blame the Government if, when integration comes it finds itself out in the cold.

The IAEA

Candid Appraisal by Outgoing Director

Dr. Sigvard Eklund being sworn in as director-general of the IAEA by Mr. Oscar Quihillalt, of Argentina, president of the Agency's fifth general conference. On their right is Mr. Sterling Cole, outgoing director-general. (U.N. Photo.)

PLAIN speaking by Mr. Sterling Cole, retiring director-general of the International Atomic Energy Agency, at the Agency's fifth general conference in Vienna, September 26-October 6, has tended to be overshadowed by the political sharp shooting that occupied much of the conference and, in particular, the staged "walk out" by Professor V. S. Emelyanov. Significant as these are in demonstrating the diversion the Agency has suffered from the objectives so optimistically predicted four years ago, Mr. Cole's criticism and advice merit recognition. And note should be taken of the efforts made by the conference, however small, for relieving financial problems and for future plans, such as consideration of the establishment of an international demonstration nuclear power plant and further study into the setting up of a centre for theoretical physics.

As last year the politics had been expected and as a consequence, although the number of countries involved in the speechmaking was greater the size of delegations on the whole was smaller. Member countries are obviously losing enthusiasm for a so-called technical organization which is increasingly being used as a political sounding board. In the words of one observer there was a distinct air of "apathy" about the proceedings. This and the rather squalid picture of inefficiency painted by Mr. Cole must have made the proceedings among the gloomiest and most frustrating to have been held, but one must at least be thankful to Mr. Cole for drawing attention to some of the deficiencies of the Agency and putting out some practical remedies. The alarming thing is that although a great number of member delegates seem to be aware of the ineffectualness of the Agency little is done to alleviate it.

Five Pronged Antidote

To improve the working of the Agency, Mr. Cole suggested that a long-term programme should be embarked upon; the financing arrangements improved, the secretariat reorganized; more authority given to the director-general; and that there should be more support from the member states in the way of materials and manpower supply. He revealed that as regards the first suggestion he had started to formulate plans for a programme and that he would pass these on to his successor. The conference did in fact accept a resolution moving the initiation of such a programme and asking for a progress report by next year. It was further specified that allowance should be made in the programme for difficulties encountered in the financing of the Agency's operations.

This factor had also been considered by Mr. Cole who pointed out that under the present arrangements planning on a yearly basis was difficult while long-term programming was impossible. He thought the solution could be found in the consolidation of the operational and regular budgets. Alternatively more research and technical assistance activities could be financed from the regular budget, which is of course based on fixed assessments from member states.

Although some delegates obviously saw the need for some change on these lines the nearest the conference achieved in improving the financing arrangements was to pass a resolution moving that member governments made voluntary contributions to the general fund at least as large proportionately as their assessed contributions to the regular budget. Russia opposed the resolution on the grounds that because it tended to transform voluntary contributions into compulsory ones it was against the general principles of the United Nations. Russia also has a grudge against giving the IAEA money because, so she claims, there was undue delay in making use of her last voluntary contribution. Mr. Cole denies the charge and lays the blame for any delay on the Soviet Union.

Just as Thorny

Moves to change financing arrangements are obviously going to have a difficult passage and so, it would appear, are moves to reorganize the secretariat. Having found that his recommendations for improving the staff fell on deaf ears when presented to the board of governors, Mr. Cole tried them out on the conference. He told them that the present structure of the secretariat lacked consistency, created avoidable administrative complications and produced areas of duplication and so created an exaggerated amount of internal co-ordination. Mr. Cole could not have been more denigrating of the organization he has had to be in charge of over the past four years—but still, so it would seem, with little effect.

The trouble about making changes, as Mr. Cole well knows, is political. Even now there is dissatisfaction from some member states about the distribution of senior posts within the secretariat from the geographical point of view and any attempt to change these will have to be made with great delicacy. Dr. S. Eklund, the new director-general, himself the centre of a political storm, has promised to look into this matter and with the help of the board make necessary improvements.

It was Dr. Eklund's appointment that caused Professor Emelyanov to walk out of the conference. The Russian bloc and some of the non-committed countries declared that Dr. Eklund was merely the tool of the Western countries and that if the director-general were to be truly impartial he ought to be selected from an Afro-Asian neutral country. Professor Emelyanov even went so far as to besmirch Dr. Eklund as a scientist and a man of integrity. The Swede was eventually elected by 46 votes to 16 with six abstentions.

As controversial as the question of finance and reorganization is that of giving the director-general more authority. Mr. Cole feels that the director-general should play a leading rôle where administration and implementation of broad policy decisions are concerned, and that the number of board meetings each year could be drastically reduced.

Although no direct reference was made to this particular suggestion during the conference, once or twice opinions were given on other matters which showed which way certain countries would turn on this point. Mr. Cole was, for instance, criticized by the Pakistan delegate for discussing on his own initiative with Yugoslavia the possibility of the IAEA supporting a power reactor project in that country. In another case, two amendments were made to resolutions accepting the regular and operational budgets which were aimed at preventing the director-general from engaging laboratory staff without authority from the board of governors. The amendments, which were not accepted, were put forward by Czechoslovakia, the U.S.S.R., Bulgaria, Poland, the Ukraine and Ghana.

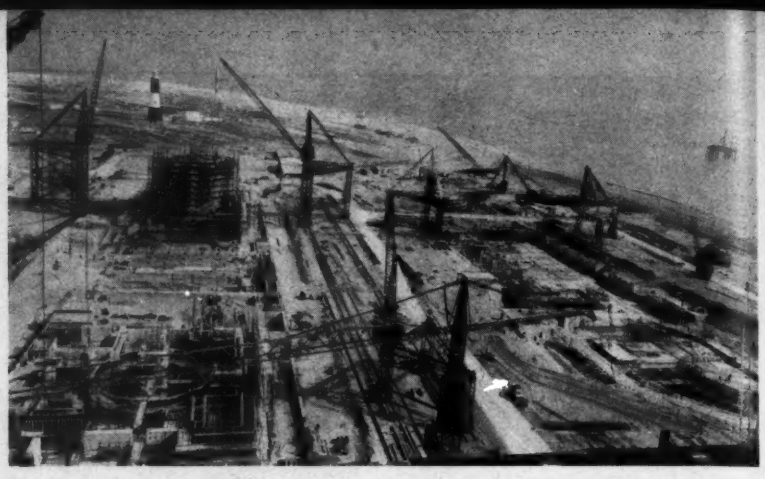
The West Not Blameless

Although much of the obstructionism that goes on at the Agency conferences can be laid on the shoulders of the Soviet countries and their allies—such as rebuking the Agency for its study on Copenhagen as a port for nuclear powered ships, bringing up the question of Britain's disposal of active waste at sea—the Western countries are not always helpful in their own actions. The Agency statute provides for a review of the statute after the agency's fifth year, which it is now entering.

In view of the state of the Agency there would seem to be every good reason for carrying out such a review. Instead, the conference, on a resolution moved by the Iran delegation, decided to postpone it for three years, the purpose being to give the new director-general time to fully acquaint himself with the Agency's work and activities. Support came from the U.K. and other Western countries, opposition from the Soviet Union.

As in previous years the questions of Hungary's membership and China's omission were discussed at some length and heatedly, again with no satisfactory results.

World Digest



View from the Goliath in use on the site of the Dungeness nuclear power station.

International

A diplomatic conference on international maritime law at which a third party liability convention for nuclear ship operators will be finalized has been scheduled for Brussels, January 22-29. A draft of the convention drawn up by a working committee formed as a result of the last conference, held in Brussels during April of this year, has been circulated by the IAEA to member states and organizations and is now expected, with some modification, to be approved.

At last the contract for the 242 MW(e) PWR Sena project at Chooz has been signed. It will be built by Westinghouse, Ateliers de Constructions Electriques de Charleroi, of Belgium, and Framatome, of France. There has been a delay due to the uncertainties of the Belgian shares in financing of the project since July, 1960, when a letter of intent was signed. Euratom have already decided to provide $8 million towards the project and it is expected that it will benefit under the second joint U.S.-Euratom power reactor programme (see page 447). A brief description of the plant appears on page 465 of this issue.

A meeting of top level experts from OECD countries to discuss new methods of international co-operation has been convened for October 25 in Paris. The meeting will discuss the implications and suggestions of Dr. L. Kowarski's report on "New Trends in Atomic Research and Their International Significance" (*Nuclear Engineering*, August, 1961).

The ENEA's third annual report was presented to the consultative assembly of the Council of Europe in Strasbourg on September 26 by Dr. S. Balke, German Federal Minister for Nuclear Energy and Water Economy.

United Kingdom

Queen's University, Belfast, has set up a committee to study the possibility of the university acquiring a reactor. Its prime utilization would be as a teaching tool, but would also be used for the production of isotopes for medical and other purposes. The committee is headed by Dr. K. G. Emeleus, professor of physics at the university and adviser to the Northern Ireland Government on nuclear matters. The source of finance is not disclosed.

To mark the opening of Calder Hall by H.M. the Queen five years ago (October 17, 1956), the AEA recently invited journalists to tour the works and discuss with the staff operational experiences since the opening.

A 25% reduction in the price originally announced for the 400 tonnes of fuel to be supplied by the AEA for use in the Latina station has been made. According to reports it is now about £14 000/tonne; less, incidentally, than the price for overseas stations forecast in *Nuclear Engineering*, March, 1960. It is not however a general price, contracts for each station having still to be separately negotiated.

Capital expenditure by the CEGB during the year ended March 31, 1961, amounted to £196·2 million, of which £53·5 million was spent on nuclear power stations, according to the board's latest annual report. Expenditure on nuclear fuel, representing payments to the AEA amounted to £3·2 million.

Operation of the DFR was started in early October at low power. The level will gradually be raised until about 20 MW(th) is reached some time next spring. Highest level the reactor has been operated at since it went critical last November was 1·4 MW in February. Operation at higher levels could not be made until the gas entrainment problems in the coolant had been solved.

Officials and representatives of local authorities, Government departments and trade unions in the Barrow-in-Furness area have been invited by the Admiralty to form a local liaison committee for the purpose of assuring the general public of the safety of the *Dreadnought*, which is being built there and which will carry out her sea trials during next year. The committee will also have the task of creating administrative machinery to be brought into effect in the event of a serious accident. A meeting to form the committee has been called for November 15.

Australia

Closing down of the Radium Hill uranium mine has been recommended by a South Australian Government committee on the grounds that it is no longer competitive with other mines either in Australia or overseas. At one time it was one of the major sources of uranium in the Commonwealth. It is believed that the present situation has been aggravated not only by the lack of world demand for uranium but also because of the central government's decision to exploit the newly found deposits at Rum Jungle (*Nuclear Engineering*, May, 1961).

Belgium

Fuel for BR3 was recently delivered to Mol by Westinghouse Electric. Although this reactor was completed in 1960 there has been a delay in the fuel delivery due to legal difficulties. Whether loading and criticality are now imminent, however, is not known.

Brazil

With a new political regime in power the future of the proposed 300 MW gas cooled reactor in the Paraiba valley, about 40 miles from Rio de Janeiro, is uncertain. Plans for the station were announced on August 25, the day that President Quadros announced his resignation, and tenders were to have been invited in September. Optimistic about the project is Professor M. Damy, president of the AEC since April, who believes that it will go ahead although there might be a delay of five to six weeks while a "re-orientation" is going on.

It is still deadlock in the negotiations between the Ministry of Transport and the U.S. State Department regarding the admission of the *Savannah* to U.K. ports. It would appear that there are no technical objections and the U.K. technical assessment has given the *Savannah* a clean bill (subject to known troubles being eradicated, see p. 446). Basically also there are no differences regarding responsibility. There is, however, a legal point involved in that the American law which accepts responsibility for third-party liability overseas up to $500 million, includes the proviso that the ship is in fact liable. But, in British Common Law it is by no means certain that a court could rule a foreign ship liable in the event of an accident. Apparently a simple letter from the State Department or a simple modification to the Licensing and Insurance Act could bring both parties together but neither at present is willing to take the administrative trouble. No doubt when the European assessment of the *Savannah's* safety is completed and the legal implications evaluated for other countries, the necessary steps will be taken. From the slow rate at which the *Savannah* is being brought into operation there still appears plenty of time.

France

A curious case is occupying the attention of the French courts at the present time which may have repercussions of much more than mere domestic significance. Briefly the background to the case is that Mme. Majoni had been an employee of the CEA at Saclay; she fell ill and applied to the Sécurité Sociale for assistance. Her own doctor found that she was suffering from anæmia and an imbalance in the white cell count—symptoms which taken alone are not inconsistent with radiation sickness and this was accepted as cause by the Sécurité, without further investigation, who agreed to pay compensation. They then turned to the CEA to recover the sum, but the CEA did not accept liability as they contested the diagnosis, particularly in view of the woman's dosage record which showed she never received more than 2·5 rem per year, or roughly one half the ICRP limit. The law, however, does not recognize this level as having significance in France and although the dosage Mme. Majoni received is not contested, it is by no means clear yet that the court will decide in favour of the CEA. Should the decision go against the CEA then a major nuclear country will have openly disputed the ICRP levels and it seems quite possible that demands for a further major reduction in the mpls would follow in many countries.

West Germany

A Siemens-Argonaut 1 000 W reactor has been ordered by the Verein zur Forderung de Awendung der Kernenergie for installation at Graz University, Austria. This will be the first German reactor to be exported.

Greece

Co-operation with Italy on a technical level is anticipated, following a formal visit to Italian nuclear establishments by Admiral Athanasios Spanides, president of the AEC, and Professor George Pantaxis, vice president. Earlier this year discussion as to the possibility of collaboration took place in Athens.

It is reported from Rome that Greece is interested in forming an industrial atomic forum, with a view to the country subsequently joining Foratom.

Italy

Fifty Italian and Yugoslav scientists recently attended a seven-day symposium at the headquarters of the Yugoslav directorate for nuclear materials, Hergcegnovi, on the metallurgy and technology of uranium. The symposium was organized under the terms of the collaborative agreement signed between the countries last year.

India

The proposed agreement with the U.S.S.R. for co-operation covering research into natural uranium and fast reactors ("World Digest," March, 1961) was signed by Professor V. S. Emelyanov and Dr. H. J. Bhabha in Vienna during the IAEA general conference. It also covers research into thorium-uranium 233 cycles, and under it Russia will provide facilities for training Indian scientists, supply apparatus and instruments for uranium mining and small quantities of natural and enriched uranium and plutonium for research purposes.

EDF-3 EDF-2 Water tower EDF-1
Recent view of the EDF reactor establishment at Chinon.

Pakistan

Collaboration with the U.K. in the nuclear energy field is to be developed. The chairman of the AEA, Sir Roger Makins, and the Pakistan AEC, Dr. I. H. Usmani, who have been attending the IAEA general conference, have exchanged letters defining their mutual interests. Going beyond the present exchanges of reports and the training given to Pakistan personnel, provision has been made for staff consultations as well as for assistance and advice on the use of radioisotopes. The eventual supply by the U.K. of research and power reactors is also envisaged.

Sweden

Temperatures of 2–3 × 10^6 °C lasting for up to 7 msec have been attained in deuterium-tritium plasma experiments being carried out by a team at the Royal College of Technology, Stockholm. They are now constructing a machine with which they hope to attain temperatures of up to 10 × 10^6 °C.

U.S.S.R.

A team of U.K.AEA scientists headed by Sir William Cook, AEA Member for Reactors, has been visiting the country for discussions on reactor physics and experimental fast reactors. It was the second of a series of exchange visits between the U.S.S.R. and the U.K. under the collaboration agreement signed in London earlier this year. The first was made by a party of Russian solid state physicists who visited Harwell for 10 days during July. The AEA team visiting Russia, as well as Sir William Cook, included Mr. P. Brock (Dounreay), Dr. C. G. Campbell (Winfrith), Mr. A. G. Frame (Risley), Mr. P. W. Mummery (Winfrith), Dr. P. Murray (Harwell), Mr. D. C. G. Smith (Dounreay), and Dr. R. D. Smith (Winfrith).

Yugoslavia

Agreements between the IAEA, Yugoslavia and the U.S. were signed in Vienna on October 4 for the supply to Yugoslavia of a Triga reactor, about 1 300 g of 20% enriched fuel and 5 g of 90% enriched uranium for use as an "indicator material." The transfer of the uranium from the States to the Agency for delivery to Yugoslavia is taking place under an agreement concluded in 1959. Yugoslavia requested the Agency's assistance in this project earlier this year ("World Digest," May, 1961) following allotment of funds towards this project by the U.S. in 1960. Similar arrangements for the supply of a Triga and fuel to Finland were made last year.

U.S.A.

Proposals for converting the New Production Reactor at Hanford into a power plant have been finally indefinitely rejected. The House of Representatives during September defeated by 251 votes to 155 a compromise bill on AEC finance for new or expanded plant. It proposed a reduction in the output of the planned generating plant by half, from 800 MW(e) to 400 MW(e). It was said that this would reduce the cost from $95 million to $58 million.

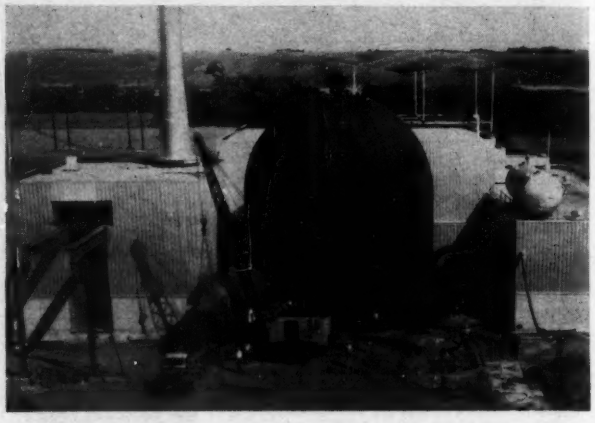
Research into the development of an advanced gas centrifuge for the separation of uranium isotopes is to be carried out for the AEC by the Garrett Corporation, AiResearch Manufacturing Division, Los Angeles. A costed contract is expected to be negotiated with the company and for the first year it will provide for work estimated at $750 000. Basic research into gas centrifuging is currently being carried out for the Commission at Virginia University, while experimental work is being undertaken at Oak Ridge. Because of the potential significance of centrifuge separation to the production of weapons the programme for its development is carried out on a classified basis. Provided the relevant security measures are observed, however, private industry can have access to information resulting from the programme for peaceful uses.

Over $285·6 million worth of nuclear energy products were delivered by private industry during 1960, according to the Department of Commerce, over $43·6 million more than the value of goods delivered in 1959 and over $123·9 million greater than the 1958 figure. The 1960 total, which covers exports as well as deliveries to U.S. Government agencies, includes $12·4 million for reactors; $11·9 million for reactor vessels and tanks; $19 million for boilers and condensers; $81·2 million for fuel and control rods ready for installation; $21·4 million for pumps; $8·3 million for valves; and $30·9 million for radiation detection and monitoring equipment. The balance is made up from values of deliveries for such items as coolants, moderators and hot laboratory equipment, radiation sources, etc. The items which accounted for most of the increase between the 1959 and 1960 figures were fuel and control rods. This was largely due to the increased number of deliveries of complete cores for naval use.

A digital computer study of the Canadian reactor, Candu, is to be made for the AEC by the Allis-Chalmers Manufacturing Company. Its purpose is to determine the power generating characteristics of the core. The study is to be made under the terms of the collaborative agreement between Atomic Energy of Canada and the AEC.

Shippingport reactor has been closed down in order to load the third set of 32 enriched seed elements to go with the original blanket elements. Start-up is expected in November and the new combination should last for 15 months after which a completely new core will be installed. This will have an additional output of 50 MW which will be dumped in a heat sink now being built.

A high energy physics research centre is to be built alongside the 12·5 BeV Zero Gradient Synchrotron under construction at Argonne. There will be accommodation for over 400 scientists and technicians, and will be used not only by the laboratory's own personnel but by visiting staff.



The reactor vessel of the 66 MW Pathfinder or CRBR (Controlled Recirculation Boiling Reactor) at Sioux Falls, South Dakota, being moved into the containment building. Pre-operational tests were due to start a month later, with criticality scheduled for next spring. The plant is being built by Allis-Chalmers.

The Alternating Gradient Synchrotron at Brookhaven was formally inaugurated by Mr. Leland J. Haworth, AEC Commissioner, on September 13. With an energy output of 30 GeV it is the most powerful particle accelerating machine in operation in the Western world. The Russians have a larger machine—a 50 GeV synchrotron-phasotron—in Leningrad.

A 40 500 c Sr^{90} source has been delivered by Oak Ridge to the Martin Company for use as a power source in a U.S. Coast Guard light buoy. The buoy's generation system consists of a 10 W thermoelectric generator, into which the Sr^{90} will be loaded, a d.c.-to-d.c. converter and rechargeable nickel cadmium batteries capable of delivering 5 W at an output of 12 V. It is designed to operate for two years without maintenance.

The Illinois governor vetoed two State bills authorizing transfer from the AEC of regulatory authority over the control of radioactive materials in the state to the state government. He considered the cost of implementing such authority would be too high. Kentucky, however, has agreed to take over the relevant responsibilities and a proposal for a transfer has been approved by the AEC. This will be the first such agreement made under the provisions of a 1959 amendment to the Atomic Energy Act that allows for a transfer under certain conditions.

New Evidence on SL-1 Accident

DOUBT has been cast on the theory that the SL-1 accident in January was most likely to have been caused through the rapid and extensive movement of the central control rod. During the preliminary decontamination and salvaging work a broken rack from a control rod assembly was found on the fan floor above the reactor which was initially identified as the upper portion of the central regularity control rod assembly. According to a statement by the AEC, "Further investigation of the status of the central control rod at the time of the incident indicates that the control rod extension was 'frozen' at a point below the top of the reactor due to collapse of the control rod expansion guide tube. At the time that the control rod extension froze, the central control rod had been withdrawn three inches but still extended through the reactor core. This seems to cast doubt on earlier theories that the accident could have been induced by rapid and extensive motion of the central control rod." Meanwhile, removal of equipment from the fan loft above the reactor continues, openings having been cut in the side and roof of the reactor building. Eventually it is hoped to cut down the entire building so as to facilitate the removal of the complete reactor vessel. It is interesting to note that since dismantling work started in June a 90% reduction in radiation levels has been experienced. Readings in the building after the accident ranged from 500-1 000 r/h. By April the maximum levels recorded were less than 200 r/h, while in September the levels immediately over the reactor and on the operating floor were, respectively, 15 and 10 r/h.

A survey of the performance in operational reactors of control rods using boron carbide powder is being made by the AEC's Division of Licensing and Regulation. Following a case of such a control rod swelling and causing it to jam in its guide, the Division feel it necessary to obtain up-to-date information on other reactors. Surveys are also being made on the anticipated radiation exposure of pressurized reactor vessels and on gaseous effluent monitoring and control practices. The radiation exposure survey is to check that the effects of radiation on vessel fabrication materials have been considered in the initial design of the vessel and that adequate surveillance is maintained. Where gaseous effluents are concerned, monitoring programmes vary from one place to another and the purpose of the survey is to provide a guide for the introduction of uniform practice.

Failure of the control rods in the *Savannah* reactor to perform up to specification was one of the reasons for the delay caused in the fuel loading of the reactor and start-up, according to Mr. R. P. Godwin, director of the *Savannah* project, in a statement published on October 5. The difficulties encountered with the hydraulic portion of the system had now been adjusted, however, and final tests on the cooling, purification, radiation monitoring, emergency shutdown and other reactor systems were under way. Fuel loading would start, the statement continues, after a 10-14 day period of preparation. This would include cooling down of the reactor from about 500°F to room temperature, removal of the reactor head and control rod drives, removal and cleaning of the reactor internals, and assembly of loading fixtures, equipment and apparatus.

Alco Products, Schenectady, have been selected by the AEC as possible suppliers of the proposed second portable Antarctic reactor, the PL-3. As reported in "World Digest," July, 1961, this plant will have an output of 1 MW(e) and 1·5 milion Btu/h in the form of steam and is scheduled to be in operation by March, 1964. It will be sited at the National Science Foundation's Byrd Station, 700 miles from the South Pole. The first south polar reactor is being built at the naval base at McMurdo Sound.

Joint U.S.-Euratom Power Proposals Invited

ANOTHER invitation to European undertakings to build American designed power reactors with aid provided under the terms of the 1958 Euratom-U.S. agreement has been made. The first, made in April, 1959, met with little response and out of the five proposals submitted only one was pursued—the 150 MW BWR at the mouth of the Garigliano River, Italy (see page 473 for progress report).

The response to the second invitation might be little better, but at least the outcome is expected to be more hopeful. Europe is now more ready to build nuclear power stations than she was two and a half years ago and, also, the definition of American aid has been made more attractive.

Two projects most likely to be accepted under the scheme are the joint Belgo-French owned Westinghouse designed PWR plant to be built at Chooz, for which a contract has just been signed, and the German KBWP organic project. Sponsors of the Bewag project for West Berlin ("World Digest," September,1961) had plans for applying for aid, but with the political situation as it is the project looks like being postponed if not actually killed. RWE, owners of the Kahl reactor, are toying with the idea of a larger nuclear plant and have in fact been studying for at least two years British and American designs. They might now decide to plump for a U.S. reactor and accept the Euratom-U.S. invitation.

They have until June 1, 1962, when the new invitation closes, to make up their minds. Also, for a project to qualify there must be reasonable assurance that the plant involved can be built and brought into operation by December 31, 1965, and will be operated after that date for at least 10 years.

Preference will be given to proposals for reactor plants having a nuclear capacity of at least 150 MW(e), although smaller units will be considered if they present some special interest to the programme. They must be of a type carried out to an advanced stage of research and development in the States. A further condition is that at least one U.S. manufacturer and at least one from the Euratom countries must participate in important rôles in the construction of the project. In addition, the project must be based on arrangements resulting from competitive tendering.

Types of assistance offered under the co-operation are as follows:—

1. **Fuel Cycle Guarantees:** The U.S.AEC will offer guarantees designed to limit certain financial risks stemming from the cost of manufacturing fuel elements and the length of time they can be burned in the reactor. These U.S. Government guarantees will be offered only to the extent that equivalent or better guarantees are not available commercially and will supplement, not supplant, commercial guarantees.

2. **Long-term Fuel Supply:** The AEC has agreed to sell or lease to the Community a net amount of up to 30 000 kg of contained U^{235} for use in the joint programme at prices comparable to those offered U.S. reactor operators.

3. **Deferred Fuel Payment:** Euratom will buy the initial fuel inventory on a deferred payment plan under which payments on principal would be deferred up to 10 years but an annual interest charge of 4% would be made on material not paid for.

4. **Lease:** An optional plan of lease has been offered to Euratom under the same financial terms as apply to domestic leases subject to the amendment of the agreement to permit leasing of materials.

5. **Market for Plutonium:** The AEC is authorized, over a 10-year operating period, to purchase up to 4 100 kg of plutonium recovered from reactors in the programme at the prevailing U.S. fuel value. Currently, this value is $12/g.

6. **Capital Loans:** The U.S. Export-Import Bank has authorized a line of credit to the Community of up to $135 000 000 to be available at 4½% interest on a project-by-project basis, but the line of credit for one project cannot exceed 40% of its total capital cost. The U.S. credit will be used for the acquisition of equipment, materials, and services required in connection with the design and construction of the reactors which are to be installed in approved nuclear power plants. The fabrication of initial fuel elements may be included.

7. **Chemical Reprocessing:** Where such services are available from the AEC to U.S. licensees, the AEC will make chemical reprocessing services for fuel supplied by the States available on terms comparable to those offered U.S. reactor operators.

Orbits . . .

RUDELY booted from our usual place and cut down—who said to size?—we still manage to get half an oar in.

Gardez l'Eau!

Elsewhere in this issue, the Halden reactor is briefly reviewed, and it is worth while drawing attention to the conservation of heavy water. While it is true, of course, that the reactor is operating at temperatures and pressures well below design figures, the loss of less than half a litre in three months is a remarkable performance—obviously no one leaves taps running at Halden.

Philanthropy?

Those who moan about the high cost of third-party insurance for cars, should try insuring a reactor for a change. In the ENEA Third Report just received, there is a trifling sum for third-party insurance on the Halden reactor, of nearly £40,000 per annum. Considering that the enclosure at Halden consists of a mountain sitting on top of the plant, it doesn't look as though the underwriters have any intention of ending up in the poor-house, does it? Even our bank manager is easier on security than that.

Talking of insurance, why not draft the *Savannah* into the U.S. Navy. They seem to be *persona grata* any time in the U.K.

Diamond-studded?

It is always confusing when somebody apparently succeeds in suspending the laws of Nature and upskittling ideas which one absorbs across one's mother's knee. Ever since we were in that undignified position for putting sand in the family mangle, we have always taken it for granted that grit caused friction and the harder the grit, the worse the wear.

Those who heard the paper, "A Novel Anti-seizure Surface Treatment," by Mr. J. Wells before the Lubrication Group of the Institution of Mechanical Engineers, however, will now know that there are possibilities in the impregnation of shafts with diamond dust, although the author is careful to point out that the process is only in the embryonic stage. The cost of the diamond dust is only about a farthing per square inch of surface.

The thought uppermost in our mind is that if this process is ever developed to cover control rods, there will be some truth in the groans of designers that the AEA and the CEGB want everything jewelled in every hole.

Calder Revisited

It was August 10, 1956, when, in consort with other journalists, we panted up to Calder Hall only to be dismissed after a couple of hours with little information other than the AEA had got a reactor built up there, but would we not bother them any more just now as they were rather busy.

Another trip has been organized to celebrate the fifth year of operation. Unfortunately, it has been laid on precisely in the middle of this journal's monthly pangs of parturition, in fact this particular aggregation of wit and wisdom will be printed before the visit takes place. We fully realize that, in shyly coming forward with our modest tribute in our hot little hand, we stand that same chance of appearing a first-class twit as does a racing tipster boldly headlining a horse on the same page as the "stop press" announces the winning of the race by another. Happily, this prospect has never been a serious deterrent. . . .

In August, 1956 (the 10th, as we recall)
A galaxy of journalists went up to Calder Hall
All sanguine and expectant—and completely unaware
The Big Boys of the AEA had just two hours to spare;
And, having rushed around the site—an enervating trot—
Were pushed into the train again . . . six hundred miles—for what?

Five years have passed; the AEA desire to make amends
They're laying on another trip for all their little friends;
No doubling round the site this time, with energy and pep,
No . . . . "Sorry, just can't tell you . . . . Well, goodbye and mind the step!"
This time, it seems, they'll Tell Us All—turn out the bag of tricks—
And give us all the secret dope . . . of Nineteen Fifty-Six. . . ?

Tangent

European Nuclear Development Effort and Industry

by DR. J. VAN DER SPEK,
(Managing Director, BelgoNucleaire)

FROM the outset it can be stated with confidence that the incidence of the European nuclear effort upon our industries will be profound. It is well known that the cost price of a kWh produced by a thermal power plant is, in the main, made up of ⅓ investment costs (depreciation and interest) and ⅔ fuel costs. For a nuclear kWh, the proportion is reversed: ⅔ investment and ⅓ fuel. Moreover, in the price of coal, there is an important "manpower" item and a relatively small industrial cost (equipment).

In contradistinction, in the price of a nuclear reactor fuel element, the unrefined uranium accounts for only a small sum, while the preparation costs (sintering and pelletizing, for instance), cladding and reprocessing constitute the major part of the total. They arise from a variety of highly industrialized activities.

This composition of the price of nuclear fuels will be accentuated as the plutonium cycle is progressively applied. Indeed, expenses for the unrefined uranium will only be concerned with the additional uranium required to compensate losses caused by fission and recycling, i.e. something very small. All the rest will be composed of costs for extraction, refining and preparation of the plutonium, which are industrial operations.

To sum up, it can be stated that, generally speaking, the production of nuclear power will give rise, almost exclusively, to extremely sophisticated industrial activities, and will lead to a gradual reduction in the toilsome work that requires less-skilled manpower, involved in the mining of coal.

Nuclear energy will, therefore, have a particularly favourable influence on industrial development and, as a result, on the general situation of labour. This is especially true as regards Europe, which, as will be seen from what follows, already has within its frontiers practically all the industries needed for the production and exploitation of nuclear power. However, it also holds true for some less technically advanced areas which, thanks to nuclear energy, will be provided with the means of setting up and developing new activities.

In this respect, it is perhaps now opportune to stress the importance of atomic power to all classes of industry. When they are reviewed, we arrive at the conclusion that practically all will be affected (in one way or another and to a varying degree) by the outcome of atomic energy developments. Some industries will have to make products either new or with hitherto unknown characteristics; others will find their production techniques modified by the use of radioisotopes, irradiation, etc.

At the present time the inference must be that no industrialist can afford to ignore nuclear energy, and must, on the contrary, be ever aware of its impact on his undertakings.

Chemical and Metallurgical Aspects

Faced with the fact that atomic energy will give rise to large industrial developments, it is useful to consider which classes of industry will benefit most from it. That is a general question applicable to all nations and all continents.

The special aspects which it assumes for each country or group of countries can only result, on the one hand, from the prior existence of particularly developed industries, and, on the other hand, from the use of a closely defined range of reactors.

Europe possesses all the techniques required by nuclear energy: it is hardly necessary to reflect to find famous names, for example, in electronics in Holland, in chemistry in Germany, in metallurgy in France and Luxembourg, in mechanical and electrical engineering in Italy and Belgium: all these undertakings are already actively engaged in production for the nuclear industry.

But the fact that Europe is concerned with all the main reactor types and does not confine itself to natural uranium units, means that the metallurgical and chemical plants for nuclear metals will be called upon to a considerable extent, because of their preponderant rôle in the plutonium cycle.

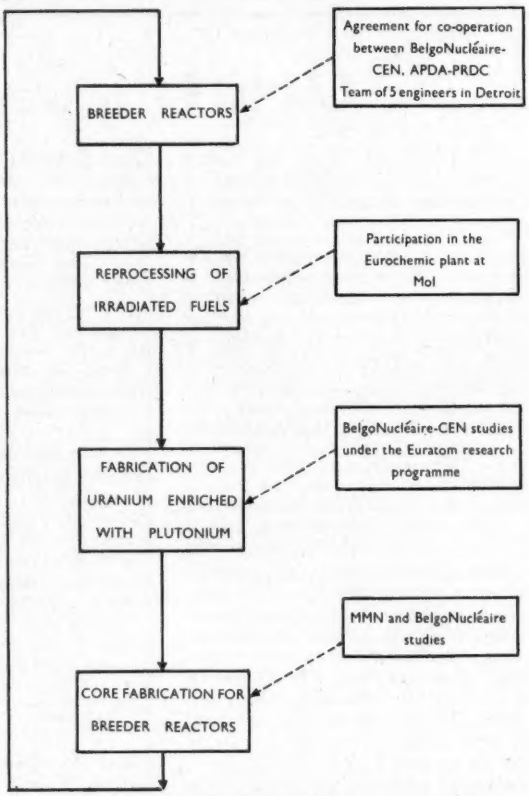
The Plutonium Cycle

With regard to the plutonium cycle, we should like to make a short digression and set out briefly some reflections on the subject, and then summarize the work devoted to it within the Euratom Community.

Fast neutron breeder reactors have been designed and built in order to take advantage of the whole of the energy potential of natural uranium by means of the transformation of U^{238} into Pu^{239}. Let us note first that as the breeders consume but small quantities of natural uranium (corresponding to the destruction by fission and the recycling losses), the influence of the price of this uranium on the production cost per kWh is very slight. This allows the use in breeders of expensive uranium extracted from poor ores, thus increasing greatly the total uranium reserves which these reactors may burn.

Second, it may be reasoned that if the two hypotheses which follow prove to be true, the fast breeder reactor might be the most advantageous class of reactor from an economic viewpoint and therefore interesting quite independently of such considerations as uranium reserves.

The first of these two hypotheses is that it *might* be cheaper to produce nuclear energy from enriched uranium than from natural uranium, the second is that it *might* be less costly to enrich uranium with plutonium than with U^{235}. Let us mention in this respect that the enrichment with plutonium is accompanied, during the generation of Pu, by a production of electricity, while enrichment with U^{235} necessitates a consumption of energy. The algebraic sum of these two terms, perhaps in the region of 8 000 kW(e)h/g of fissile material, goes on the credit side of enrichment with plutonium and consequently lends added support to the breeder reactor.


BREEDER REACTORS
Agreement for co-operation between BelgoNucléaire-CEN, APDA-PRDC Team of 5 engineers in Detroit
REPROCESSING OF IRRADIATED FUELS
Participation in the Eurochemic plant at Mol
FABRICATION OF URANIUM ENRICHED WITH PLUTONIUM
BelgoNucléaire-CEN studies under the Euratom research programme
CORE FABRICATION FOR BREEDER REACTORS
MMN and BelgoNucléaire studies

Schematic showing Belgian development work on the plutonium cycle.

These considerations show that fast neutron breeder reactors and the plutonium cycle are of great interest, and several Euratom countries are consequently actively setting up projects.

France has an excellent team of specialists in fast breeder reactors; an experimental reactor of this type (Rapsodie) is being built at Cadarache, while there is a plutonium extraction plant at Marcoule. Germany also has just assigned a large number of research workers to the study of breeders, while the Karlsruhe Centre, built jointly by the German Government and Euratom, is devoted to transuraniums, i.e., mainly to plutonium.

Belgium has studied systematically all the stages of the plutonium cycle which, in this country, is considered as a whole; with the support of the Centre d'Etude de l'Energie Nucléaire, BelgoNucléaire has concluded an agreement for co-operation with the two groups, Atomic Power Development Associates and Power Reactor Development Company of Detroit, Michigan, U.S.A., constructors of the Enrico Fermi power plant (*Nuclear Engineering*, Sept., 1961), where six Belgian engineers have spent five years. The Belchim company participates both financially and technically in building the Eurochemic plant for reprocessing irradiated fuels (and recuperating plutonium). To complete the cycle, BelgoNucléaire, in partnership with CEN, is studying, under contract to Euratom, the manufacture of plutonium enriched uranium.

Deficiencies and Excesses

Generally speaking, we may consider that European industry is equipped to meet the requirements of nuclear power development. Deficiencies, which could rapidly be remedied, would only be found in very special technological branches such as those of heavy water, liquid sodium, and some rare metals used in shielding and control rods. As these techniques are closely linked to specific types of reactors among which no definite choice has yet been made, there is no urgency to study them intensively; it is simply necessary to devote to them, with forethought, moderate though continual action.

Besides the deficiencies, there are also excess capacities. Without being ironical, it must be said that these over-capacities exist in the nuclear teams set up by the industrial companies which, owing to the slower-than-expected development of atomic energy, have not always found immediately as much work as they had hoped for. This lack is partially met by the research contracts granted by Euratom and the national commissariats. Moreover, it is reasonable to suppose that nuclear energy will undergo rapid growth when the working of the first power stations has provided the constructors with more experience and their operators with more economic data. It must then be expected that the present teams will very soon become insufficient in number.

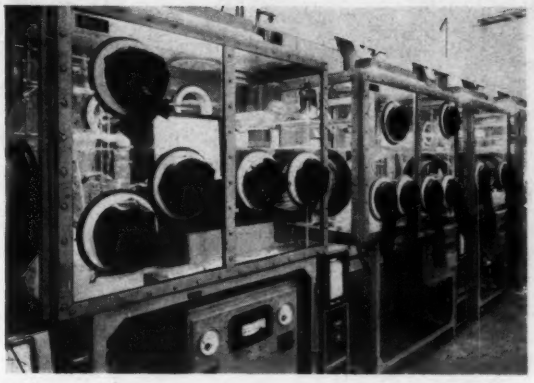
Industrial Organizations

It may be interesting to say a few words concerning the industrial organizations (apart from the national commissariats), to which these teams belong.

There are, first of all, some large manufacturing companies, such as Siemens and AEG in Germany, Thomson-Houston in France, Fiat in Italy and ACEC in Belgium, which have set up from scratch nuclear divisions, and which agree to undertake the complete study, design and construction of research and power reactors, and which, in addition, have often reinforced their competence by concluding agreements for co-operation or licence with experienced English and American constructors.

There are also companies which have been set up to exercise certain specific activities, for instance the manufacture of fuel elements (Cerca in France, Nukem in Germany, Italatom in Italy, and MMN in Belgium).

Lastly, various nuclear design offices and consulting engineers are independently highly active. Indatom, in France, has built notably the Mélusine reactor at the Grenoble Centre; Interatom, in Germany, is studying, in association with GAAA in France, the Essor reactor for Euratom; the Bureau d'Etudes Nucléaires set up in Brussels by the main Belgian electricity companies, has been entrusted with important assignments as consulting engineers, in the service of the plant owner, for the high flux reactor and SENA's Ardennes power plant project. Also in Brussels, BelgoNucléaire, which was formed by the main Belgian manufacturing, chemical and metallurgical companies, is building research reactors and studying various types of power reactors, notably fast neutron breeders, and a remarkable design of a spectral shift reactor, called Vulcain, the work of the Belgian engineer, P. Maldague.



Glove boxes in the ceramics section of BelgoNucléaire's plutonium laboratory at Mol.

It is still too early to say which, among all these types of industrial organizations, are those that will prove useful and will therefore survive, and which are those destined to disappear. The take-over a few years ago in the U.S.A. of the General Nuclear Engineering Corporation by Combustion Engineering, and the very recent merger of NDA with the nuclear divisions of Mallinckrodt Nuclear and Olin Nuclear Fuels are events which give food for thought.

In another connection, the British industrial nuclear groups play a role which could not be done by any other organizations, and the structure of companies such as Indatom and BelgoNucléaire is very similar to theirs. There are, moreover, in other fields similar undertakings which give complete satisfaction.

It is therefore too soon to draw definite conclusions. The only thing to be done at present is to prepare for the future by forming competent, well-organized teams, by putting them to work, and by endeavouring to discern which technical solutions we are turning towards.

Supranational Organizations

Placed over the private industrial companies dealing with nuclear power, there are, naturally, the commissariats for each country, Euratom, the International Agency for Atomic Energy in Vienna and the European Nuclear Energy Agency of OECD in Paris. At their respective national levels, the commissariats fulfil a role very similar to that assigned to Euratom by the Treaty of Rome, to which we can therefore confine our examination.

The influence of Euratom upon the development of the Community's nuclear research is particularly favourable and it is to be hoped that more and more this will be the case for the nuclear industry. By creating or taking over nuclear research centres, either completely or partly (Ispra, Karlsruhe, Petten, Mol, etc.), Euratom has secured an outstanding complex devoted to fundamental and applied researches, in whose activities the industries of the member countries participate. It grants to these industries research contracts which, among other advantages, lead to the formation of highly competent and well-trained teams of specialists.

Lastly, its programme of support for the power stations makes for concrete results, while its Nuclear Fuels Supply Agency has been adapted with flexibility and realism to the radical change in the state of the uranium market since the Treaty of Rome was negotiated.

On the whole, the supranational nuclear organizations give the European nuclear energy industry strong and efficient support, by orientating and backing up its work, by co-ordinating and rationalizing its efforts, and also by providing our industries and our specialists with numerous and fruitful opportunities for meeting.

Euratom's Research and Development Programme

Euratom's executives (left to right) M. de Groote (Belgium), vice-president Medi (Italy), president Hirsch (France), Herr Krekeler (Germany) and M. Sassen (Netherlands).

IN drawing up the Treaty creating the European Atomic Energy Community (Euratom), the representatives of the member countries aimed at a measure of co-ordination of national research programmes in order to avoid useless duplication of effort and facilitate the practical application of scientific results. It was recognized that the Euratom Commission could not do this work adequately if it did not have a competence of its own, which it also could use for carrying out additional research work.

One of the main tasks of the European Commission is therefore that of getting well acquainted with national efforts. National programmes are communicated to the Commission, which examines them in the light of the general evolution of research and may grant certain forms of aid to those programmes whose implementation is of interest to the Community.* The large number of multinational working groups which have been set up since the Treaty came into effect testify to the Commission's activities in this direction.

Furthermore, investment projects for nuclear installations have to be submitted to the Commission, which after discussion with all those concerned, formulates advice.† Finally, enterprises which are of primary importance for the development of the nuclear industry in the Community may be granted the statute of joint enterprise, thus benefiting from important economic advantages such as tax exemption, financial participation by the Community, etc.‡

We cannot go here into much detail concerning all these activities. Nevertheless, it should be emphasized that the co-ordination of national research programmes is one of the matters which are of permanent concern to the Commission, and that as it makes progress national programmes and Community programmes will tend to be more and more interwoven.

Arrangements such as contracts of association or joint enterprises allow of an interpenetration of programmes in important fields, a process which is accentuated by numerous meetings of experts on particular points. This aspect of the Commission's action should not be overlooked.

Apart from the general task of co-ordination, the research and development projects directly entrusted to the Commission are being carried out during the first five-year period (1958-1962) in accordance with a general programme annexed to the Treaty, for which a credit line of $215 million has been opened. This programme provides, on the one hand, for the creation of a Joint Nuclear Research Centre to deal in particular with research and development work on prototype reactors, and on the other, for supplementary research, carried out under contract, in fields such as nuclear fusion, chemistry, physics, electronics, metallurgy, biology, etc.

In setting up the joint centre, the Commission has taken great care not to increase unduly the number of nuclear centres already created (if not fully developed) in the Community. It has been fortunate in finding a very co-operative attitude in the member states. In this way all four establishments of the Common Research Centre which have been created incorporate national laboratories which have been, totally or partly, transformed into Community Centres. These are:—

1. Ispra (Italy), entirely made over to Euratom.
2. Petten (Netherlands), where the Euratom and national centres are adjacent;
3. Geel (Belgium), where the Euratom Bureau of Nuclear Standards is located inside the Mol CEN;
4. Karlsruhe (Germany), where the transuranium laboratory is located inside the German KBBG.

Thus the Commission has been able to start work more quickly than it could have otherwise, infrastructure expenses have not been unduly increased and joint contributions of the member states and of the Commission ensure a quicker development of the centres than would purely national action.

In addition to work done in its own establishments and to usual research contracts, the Commission has entered into a number of associations with national institutions.

These associations deal with rather large subjects (details will be found later in the text) and are extended over a number of years. Joint financing by the partners is supplemented by joint direction§ and, above all, by the creation of a joint team. The original national research group is expanded by Euratom staff, in general of different nationality from that of the partner institution.

In this way, again, the Commission secures quick action, and increases the volume of valuable national undertakings, together with their progressive transformation into Community operations.

Financing

The relative importance of the various methods of action just summarized is shown in the fact that, in 1961, the Commission expenditure is distributed as follows (in round figures):—

Direct operation of the Common Research Centre	37%
Ordinary R and D contracts	28%
Association contracts	35%

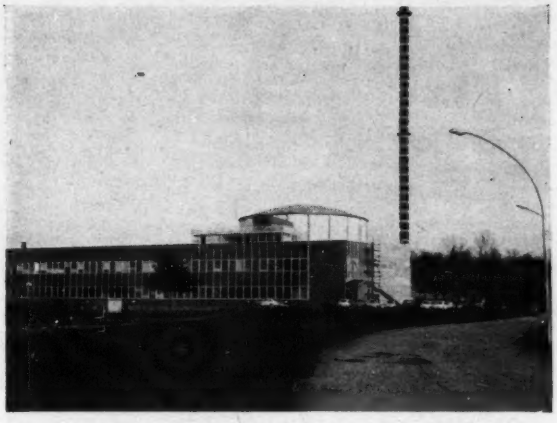
Ispra Research Establishment

Under an agreement with the Italian Government, which came into force in September, 1960, the international team working at the Ispra research establishment (1 100 people at the end of 1961) will be built up to a staff of 1 500 by the end of 1962. The necessary construction programme is under way and will make available to the Commission about 55 000 m² of laboratories and other buildings.

The Ispra research centre, intended as a general-purpose establishment, may be called upon to carry out a wide range of assignments. Work during the first few years, however, will be centred on the development of the heavy water/organic reactor (Orgel) which is being carried out in close collaboration with the Canadian AECL. As from 1961, Ispra has already at its disposal important analogue and digital computers including a transistorized IBM 7090, which will be used for reactor calculations and for general research on the treatment of non-numerical data. In this latter field, close liaison is maintained with all interested parties outside the Community.

After a 2-year transition period, during which the Italian authorities will be responsible for ensuring operation in

* cf. Art. 5 and 6 of the Treaty.
† cf. Art. 41 and 42 of the Treaty.
‡ cf. Art. 45 to 51 and Annex III of the Treaty.
§ The partners delegate the necessary powers to a "managing committee."



At Ispra, N. Italy, Euratom are operating the heavy water moderated CP 5 type research reactor.

accordance with a programme laid down by a joint board, the Ispra I research reactor will be taken over by Euratom. Three major scientific departments have been created, namely reactor physics, materials, and engineering. A number of smaller units deal with such subjects as magnetic resonance, direct conversion, etc.

Some $34 million (including a $9 million contribution from the Italian Government) will be committed for the development of this centre before the end of 1962. An additional $16 million is earmarked for operating during the same time.

Central Nuclear Measurements Bureau (Geel, Belgium)

This establishment, which is situated in the vicinity of the Belgian research centre at Mol, specializes in work on nuclear measurements with particular emphasis on the improvement, storage and distribution of primary standards and the development of measuring apparatus and methods. Its programme is decided in close relationship with the European-American Nuclear Data Committee of which the United States, the United Kingdom, Canada, the Euratom Commission and the ENEA are members.

A number of major pieces of apparatus will be required under this programme. For neutron cross-section measurements, in addition to the possibility of using choppers at the Mol reactors, the SNMB will have a pulsed 3·5 MeV van de Graaff and a 40 MeV linear electron accelerator. The study and construction of a high resolution electro-magnetic isotope separator are being considered.

The SNMB staff will be progressively enlarged from the existing 70 to about 180 persons by the end of 1963. Credits of $4·5 to $5·5 million have been provided to cover laboratory construction and equipment during that period (including a Belgian contribution to buildings).

Karlsruhe

Negotiations have been concluded with the German Gesellschaft für Kernforschung for the setting up at Karlsruhe of a European transuranic elements laboratory, and an agreement signed at the end of last year.

This laboratory should begin work as soon as the first buildings are ready (hopefully in 1963). It will carry out research, development and experimental work on the applications of the transuranic elements with particular reference to the development of plutonium-based fuels in thermal and fast neutron reactors.

Plans have been set up for the construction of a research complex with an approximate surface of 20 000 m² including hot cells, technology hall and the necessary supporting laboratories (physics, chemistry, metallurgy and ceramics). The initial building and instrumentation costs are expected to be around $15 million (40% of which will be supported from German sources). The Commission is planning for a staff of about 50 by the end of 1961, rising gradually to a maximum of 250 in a couple of years. The present staff is engaged in planning the buildings and equipment or in R and D work carried out under contract with various laboratories.

Petten

Negotiations for the setting up of a research centre at Petten, Netherlands, were concluded in July, 1961. The Commission intends to set up at the Dutch centre at Petten a general-purpose branch of its own joint centre which, in the initial period, will concentrate on the operation of the ORR type reactor, now nearing completion under the responsibility of the Reactor Centrum Nederland.

R and D on Reactor Prototypes and Experiments

For carrying out its programme in this field, the Commission can sponsor work directly at its Joint Research Centre establishments, or associate with projects elsewhere; it can also work through contracts.

Dragon Project. The Commission, acting on behalf of the six member countries, contributes 43·7% of a total project budget of $28 million. Thirty-five of the engineers working on the project have been seconded or sponsored by the Commission; these include the chief engineer, deputy chief engineers and one of the deputy heads of the research department.

Halden Project. The Commission, acting on behalf of the six member countries, contributes 27·3% of the project budget. This includes expenditure necessitated by the extension of the Halden Agreement. Six engineers of Euratom's staff or sponsored by the Commission are assigned to this project.

Suspop Project. The aim of this project, which has been under way since 1959, is to study, build and operate a reactor experiment in conjunction with the Dutch KEMA laboratory. The programme involves basic research on the following problems: methods of preparing UO_2 and ThO_2 suspensions, purification of suspensions, suspension rheology, methods of carrying out measurements in a highly radioactive environment, development and testing of circuit components (valves, etc.), remote-control maintenance and core kinetics. This programme together with systematic research on the influence of various parameters is being carried out with subcritical and zero-power critical models. After construction of the reactor experiment (250 kW or more) it will be possible to study under radiation, in fluxes similar to those of a realistic prototype, various phenomena (e.g. erosion), the suitability of certain items of equipment (e.g. pumps, purifying equipment) and the behaviour of the suspended particles.

The project now employs some 50 engineers and technicians, three of which have been sent or seconded by Euratom. The present contract with KEMA runs over a period of three years and the Community contribution during this period (2/5 of total cost) is expected to amount to $1·4 million.

*Orgel**. As enriched uranium is not being produced within the Community at the present time, it was decided, at the beginning of 1960, to make a particularly thorough study of the heavy water moderated, organic liquid cooled, natural uranium fuelled reactor type. This type has not yet been studied in the six countries, but work has already been carried out in Canada under the OCDRE project, and close contact is being maintained with this project. The tasks are gradually shared out on the basis of the progress made by each of the two parties. The Commission, for example, will concentrate on uranium carbide fuel, while AECL is mostly considering uranium oxide.

The development of the Orgel project calls for an extensive research and development programme involving studies in such fields as neutronics, chemistry (behaviour of organic coolants under various reactor conditions; development of economic cooling materials), heat transfer, technology, metallurgy (study of natural uranium in its different forms, SAP, etc. . . .; irradiation tests on fuel elements and structural materials, corrosion, etc. . .) and reactor optimization. The Commission's plans for the immediate future cover primarily research on the reactor core and on fuel element geometry, mechanics, chemistry and the control devices.

In addition to this basic work, the development of the project calls for the construction of facilities to test and improve the

* A description of the Orgel programme will be published in our December issue.

knowledge obtained. This programme is being carried out at Ispra in three stages:

1. An elaborate critical assembly (ECO) will be operating at Ispra in 1963.

2. At the same time, a specific test reactor (Essor) is being designed which will enable testing of fuel elements as well as of coolants and structural materials. This reactor will include several experimental loops as well as a statistical testing zone. Detailed specifications have been worked out. The decision to build should be taken in the middle of 1962.

3. Subject to experience thus gained, the construction of a power prototype could be considered in liaison with interested utilities.

In addition to general equipment and operation expenses at Ispra, $17 million have been earmarked during the period 1960-1962 for specific study and development of Orgel. During the actual development of the Ispra Centre, an important part of the Orgel research programme is carried out under contract with Community research laboratories and industry.

Fast Reactors. The importance of using all uranium resources, and therefore plutonium, leads the Commission to take an active interest in fast reactors.

Contacts have therefore been established with a number of interested organizations in the Community with a view to bringing their means and projects into an overall European programme. The United States Atomic Energy Commission has recently declared its willingness to co-operate in this effort and the U.K.AEA has considered exchanges in future, in particular in the field of critical fast neutron experiments; such co-operation would provide important support to a relatively young Continental effort in this field.

The Commission's programme will therefore include a series of activities in association with the French CEA, the activities of the Joint Nuclear Centre, and such work as may be decided upon in collaboration with the Karlsruhe research centre. In addition a Belgian firm has built up, in relation with AIDA, a small but well-trained team in fast reactor technology.

Work is already under way with the French CEA and Belgo-Nucléaire on the problems to be solved prior to the conceptual design stage of an elaborate fast critical assembly. The work of BelgoNucléaire comes under a contract with the Euratom Commission.

The programme to be carried out over the next five years in association with the French CEA would include study, construction and operation of "Rapsodie," fast critical assembly construction and operation, development of plutonium fuels and pyrometallurgical reprocessing, as well as conceptual design and R and D work on a power prototype on which construction might start in 1967.

This and other work is now under discussion, so that only broad outlines can be given at this stage.

Participation in Power Reactor Construction and Operation

The Commission has decided to participate (up to an amount of $32 million) in the construction and operation of power reactors to be built by Community enterprises. The Community contribution will help establish the fuel manufacturing industry in the Community, and will assist utilities to meet high operation costs associated with the starting up period of nuclear stations.

As a counterpart, Commission staff, or Commission sponsored engineers, will share in the work and the Commission will obtain free access to all knowledge obtained in the course of design, construction and operation of the power plants. Such knowledge will be made available to all interested parties within the Community.

Community participation is, so far, being considered for the following three reactors:—

Plant	Country	Type	Community participation up to
SENN	Italy	BWR	$7 million
SIMEA	Italy	Calder	$4 million
SENA	France	PWR	$8 million

The 20 MW heavy water moderated ORR-type research reactor at Petten, Holland.

Nuclear Merchant Vessels

A $1 million R and D contract has recently been signed with Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt and Interatom (Germany) to establish construction plans and collect sufficient data to assess the possibilities of constructing a merchant vessel with OMR propulsion. Other proposals are being examined.

Joint U.S.-Eratom R and D Programme

The Agreement for Co-operation concluded in November, 1958, between the United States and Euratom calls for a joint research and development programme to be carried out both in the U.S.A. and in Europe, with the purpose to improve the performance of reactors scheduled for construction under a joint reactor programme, and to reduce fuel recycling costs. The programme also includes plutonium recycling and other problems related to the types of reactors which come under the reactor construction scheme.

Following an invitation for proposals published in January 1959, 367 research proposals have been received to date. Whereas a large number of proposals have been rejected or withdrawn (some are still under evaluation), the Joint Research and Development Board set up to evaluate entries has authorized the negotiation of 64 contracts of which 50 have already been concluded in the Community countries (for a total appropriation of slightly more than $9 million) and 19 in the U.S.A.

Research in progress under this programme relates primarily to the fabrication of UO_2-based fuel elements, plutonium recycling, cladding materials, thermal exchange, corrosion and a number of definite problems in the field of welding techniques, special steels, etc. . . . As reactors come into the joint reactor programme specific development projects will come under the joint R and D programme, in addition to the above-listed subjects of general interest.

Twenty-five Euratom engineers currently participate in several programmes. In addition, a number of engineers work under research projects carried out in the United States under the joint programme.

Materials Testing Reactors

As a result of an agreement signed in 1960 with the Belgian Centre d'Etude de l'Energie Nucléaire, the Community shares in the operation of the BR-2 high flux reactor and auxiliary facilities for the preparation and examination of irradiated samples.

The agreement runs over a period of 20 years and involves Community expenditure to an amount of about $20 million during the first period of five years. Some 140 staff (including 40 from Euratom) are already working on the site and 60 more will be required as the reactor becomes operational.

As a number of other testing reactors will come into operation in the near future, such as the one at Petten, the Commission is endeavouring to co-ordinate irradiation programmes in order to ensure the best possible use of existing facilities, including hot laboratories.

Controlled Thermonuclear Reactions

The Commission's action in this sphere comes under the two contracts of association concluded with the French CEA and the "Institut für Plasmaphysik" at Garching.

The association with the CEA covers the entire non-military French work in this area of research. Initial work has been focused on fast discharges, magnetic mirrors, especially of the pyrotron type, and the formation and use of thin plasma layers. An amount of $9 million has been committed on joint research over a period of three years (1959-1962) and more than 100 scientists are at work at the Fontenay-aux-Roses laboratories, of whom over 20 are non-French Euratom staff. An important subcontract was concluded in 1960 between the Euratom-CEA partners on the one hand and the Italian CNEN on the other, which will be carried out at the Frascati Centre near Rome. Some 60% of the resources necessary to this latter contract ($3 million over a period of 2½ years) have been provided from the funds of the Euratom-CEA association.

A second contract of association has been recently signed with the Institut für Plasmaphysik for which Community funds of $2·5 million are being provided over a period of three years. The association's total expenditure during this period will run to about $7·5 million. The preliminary programme encompasses a number of pinch experiments, an investigation into the physical properties of a stationary plasma, a study of high density arcs, an examination of various technological problems and theoretical research into several branches of plasma physics.

Two smaller contracts, in Germany (Julich) and in the Netherlands (Juutphas) are under negotiation.

Biology

An association contract in the field of animal radiobiology has been under way since 1959 with the Dutch TNO for the study of radiation sickness therapy in mice, rats, guinea-pigs and monkeys, with a special investigation in medullary grafting, and research on the breeding and use of specific pathogen-free experimental animals. The initial contract runs over a period of three years and involves expenditure of $1 million, including a $600 000 contribution from TNO.

A second association was concluded at the beginning of 1961 with another Dutch organization (ITAL) working in the field of plant biology and general applied agricultural research. Research under this contract will include an investigation into the genetic and somatic effects of plant irradiation, the use of radioactive sources for the conservation of food, and a study of the behaviour of radioelements in the soil, plants and animals.

This contract has been concluded over a period of 20 years and a maximum expenditure of $7·5 million is foreseen for the first five years of activity, at the rate of two-thirds on behalf of Euratom and one-third on behalf of ITAL, the latter providing, in addition, all buildings. Work on this project has already been started but will be gradually developed as new laboratory and irradiation facilities become available.

Apart from these preliminary actions, an overall programme has been set up and will be implemented in the coming year.

Radioisotopes

The important development of the utilization of radioisotopes expected during the next few years has led the commission to enter into negotiations with the producers in order to enable the Community to satisfy its own growing needs. These contacts should allow present production to develop, harmonize research work in order to improve the quality of existing products, develop new preparations and prevent premature investments in the field. The recovery of fission products would also come under this scheme.

During the next few years, industrial applications of radioisotopes will also be promoted. As the installation of high activity sources is not within the reach of many private organizations, the Commission intends to promote a programme which would provide utilizers within the Community with sufficient means of irradiation.

The supply of complex non-commercial labelled molecules being very difficult for research laboratories, the Commission proposes to contribute to the preparation of the most interesting products so as to put them at the disposal of as many users as possible.

Euratom's headquarters in Brussels.

Automatic Scientific Data Processing

In 1959, the Commission set up the Scientific Data Processing Research Team (GRISA) to study the possible development of a documentation machine capable of recording, classifying and reproducing scientific data relating to nuclear energy and its applications. In view of the fact that this project would obviously require considerable computing facilities, of which GRISA alone would not be in a position to make full use, the computing team and the documentation and linguistic team have been combined to form the Scientific Data Processing Centre (CETIS). This centre has been equipped with an IBM 7090 ordinator as well as an IBM 1601 and a PACE analogue computer. This equipment has been installed at Ispra to serve all the computing requirements of the joint centre.

The progress made in this work, particularly the use of the special autoprogramming languages, both on the numerical computing as well as on the linguistic side, and the lines along which the work of foreign centres has developed, have confirmed the Commission in its view that this policy of close collaboration between experts on numerical and non-numerical data can produce valuable results.

Training

In order to facilitate the training of nuclear engineers and technicians, to enable them to follow the progress made in the Community as a whole and to encourage collaboration between universities and nuclear centres, the Commission has organized, in conjunction with national research centres, practical training periods (stages) open to advanced students and incorporating the majority of the disciplines which nuclear research involves.

In 1960, about 150 such stages were made available to students within the Community. This activity will be continued and expanded in the years to come.

CONCLUSION

With public expenditure in the Community on research and development running at a rate of very roughly $400 million a year, the Euratom first five-year programme provides for additional expenditure ($215 million) of little more than one tenth. But it is hoped that the programme now under way is giving European nuclear research in general an additional thrust, particularly in such fields where hitherto little work has been done, or which go beyond the technical and financial means of individual member countries.

The preparation and discussion of the next five-year plan (1963-1967) will provide a good opportunity to assess the results obtained and to see whether the attempt described above to consolidate and expand nuclear energy R and D work in the Community has met with enough success to warrant the expansion we hope for in the future.

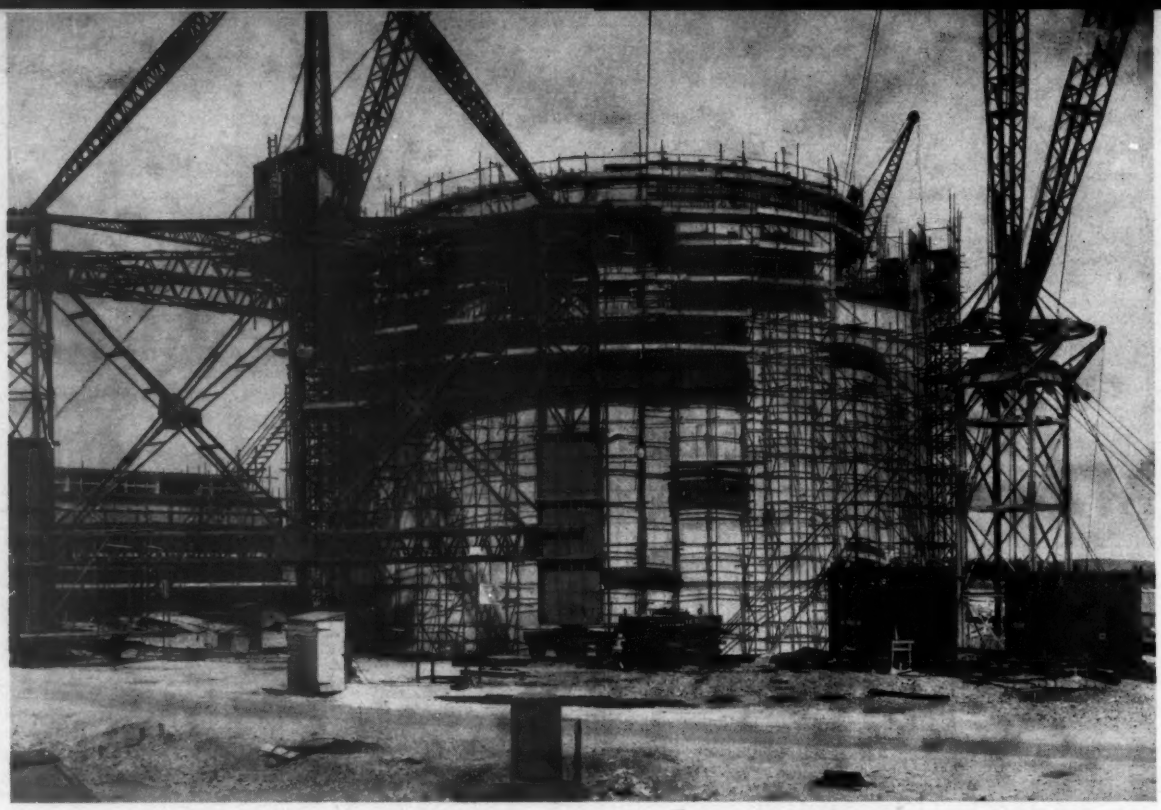


Fig. 1.—A recent photograph showing the state of current progress on the Dragon site at AEE, Winfrith. The second annual report of ENEA's high temperature gas cooled project was published at the beginning of August. This review includes changes made since its publication.

The Dragon Project: Progress Report

SINCE our last report on the Dragon Reactor Experiment (*Nuclear Engineering*, July, 1960) the work of construction has proceeded apace. Main contracts have all been placed, apart from the fission products and helium purification plant where the main design has been frozen and the specification nearly completed so that requests for tender and completion of the detail design can be sent out shortly.

Approximately 80% of the concrete work has now been completed, the outer containment vessel having been taken up to nearly roof height. Any potential leakage between lifts is eliminated by embedding plastics inserts of dumb-bell cross section. The inner biological shield is up to the control rod drive floor. The partitioning walls between the various plant rooms within the reactor building have still to be put in but these will await completion of the steel containment vessel which at present is about three-quarters complete. Present plans call for this vessel to be pressure tested in March, 1962, an early date in the overall programme having been determined in order to allow generous access to all parts of the vessel until the initial proving tests have been completed. There will be a further pressure and leak test during the reactor commissioning stages but this will be merely a final precautionary check.

Completion of the reactor pressure vessel itself has taken somewhat longer than was anticipated but the general constructional programme has been re-phased to accommodate the delay. Fabrication is, however, now complete and it is undergoing a series of tests to check its integrity; these include vacuum, hydraulic and pneumatic testing, the last being a final check with helium on the leak-tightness of the vessel. The vessel and its top cap will be delivered as two loads to the site some time at the end of the year, and the final transport arrangements of this awkward load are practically decided.

Another major item of plant, the charge/discharge machine, is proceeding satisfactorily at the contractor's works. In regard to the provision of circulators, the prototype should be ready for delivery early next year and the six required for the reactor itself will follow in the autumn. At the present rate of progress the reactor vessel should be installed and in position complete with dummy core by July of next year and fuel loading could well begin early in 1963 although the build-up of equipment within the vessel and within the reactor building requires close sequence control and any minor delays are likely to be magnified as a result of schedule distortion.

DESIGN

No fundamental changes have been made to the design of the reactor but certain important changes in detail design have been made. Originally the fuel element canning and decanning facility was to be housed inside the pressure vessel but this has now been relocated outside (but within the inner containment) following a relaxation of the demands to be made upon it. This removes the mechanisms to an area where maintenance is easier. To remove a fuel element from the core it is first lifted into the top cap, and then transferred to the seating spike located immediately below the transfer port (see Fig. 2). From here it can be drawn through a seal valve into the transfer flask and lowered into the canning cell where it is enclosed in a sealed container. A prototype of the container closure mechanism has already been built and tested and the design thus confirmed.

Small modifications have been made to the design of the pressure vessel and the bottom dome simplified by eliminating the need for access tubes to the steel samples. These samples are to be irradiated under the same conditions as the pressure vessel steel and removed at regular intervals to check the change in the ductile-brittle transition temperature. They will now be located outside the vessel rather than within. Tests on the steel will indicate any rise in the transition temperature and if necessary the vessel can be annealed at 400°C. To carry out the annealing operation the thermal shields and heat exchangers are drained of water and the circulators are driven to apply heat to the system. To reduce heat losses thermal insulation has been provided between the biological and thermal shields. The electrical heater is no longer provided.

Very good results in terms of leak tightness of flanges have been obtained with soft metal gaskets. Therefore seal welding will not necessarily be done during assembly of those flanges which are expected to be accessible after reactor operation (i.e. main heat exchanger and circulator flanges). In many parts of the circuit where non-demountable flanged joints are included the seal weld will be retained. For demountable flanges in cool areas, elastomer O-rings form an outer seal principally so that leak probes can be inserted between gasket and seal and records made of the behaviour of the gaskets under operating conditions. The vessel head will be pulled down on to the body (as will the heat exchangers) by the use of heated bolts.

Fuel Element

Although the general concept of the fuel element has not changed, certain detailed modifications have been made to the design and also to the spike upon which they sit. At the top end a metal reinforcement which envelops the top block has been introduced. This will take up the load to the individual rods if a failure in the central graphite support occurs.

Removable Spike Unit

The Dragon Reactor core contains 37 fuel elements through which fission products are continuously removed by a scavenging flow of helium. The fuel elements are mounted on removable spike units through which the scavenging flow of helium passes.

Apart from supporting a fuel element which weighs about 210 lb, and making a good gas tight seal with it, the spike unit performs the function of providing a restrictor by means of a cyclone and an orifice. In the event of a fuel element assembly being fractured or badly seated on the spike unit, the restrictor will maintain the purge flow through the other 36 fuel elements to within 95% of the intended value. In addition to acting as part of the restrictor, the cyclone will also remove from the gas stream particles of a greater size than 15 μm. These particles could contain active fission products.

In addition to a cyclone chamber and orifice the removable spike contains a fixing mechanism for securing the spike unit to a core bed plate sleeve, together with a ceramic container for collecting particles removed by the cyclone.

The purge gas flow passes from the fuel element into the spike unit, via a gas tight seal between the spherical end of the spike and the conical seat of the fuel element. The purge gas then passes down the inside of the spike unit and is directed tangentially into the cyclone chamber, where the separated particles fall into the ceramic container.

After the purge gas has passed through the cyclone it is directed through the orifice, which, together with the cyclone gives the required restriction. The purge gas flow passes out of the spike unit and into the core bed plate sleeve, via a demountable seal, and is then piped to the helium clean-up plant.

In order to determine whether a fuel element is seating correctly on a spike unit, the flow of purge gas through the fuel element can be measured by a differential pressure device. This device is connected upstream of the orifice via a capillary tube, and the core bed plate sleeve, to the purge gas in the cyclone chamber. A demountable seal provides the gas tight joint between the spike unit and the core bed plate sleeve.

Heat generated in the spike unit due to the collection of fission products in the ceramic container is dissipated to the main coolant stream by directing a small proportion of this stream between the spike units and core bed plate sleeves. Should the main coolant stream fail, it is expected that natural convection together with the thermal radiation shield fitted to the spike unit, will protect the core bed plate sleeves against damage caused by excessive heating. An excessive accumulation of fission products in the ceramic container could cause over heating of the core bed plate sleeves. In order to know when this is occurring, the temperature inside the ceramic container is measured by a thermocouple.

The leads from the thermocouple are connected via friction contacts to a terminal block incorporated in the base of the core bed plate sleeve. The terminal block is designed to make contact with the spike unit in any radial position.

Should the temperature of the spike unit become excessive due to the collection of fission products, the spike unit can be removed and a new one replaced by a special tool which is handled by the charge/discharge machine.

The temperatures at various positions along the fuel element assembly are measured by thermocouples. The connections from these thermocouples are made via friction contacts mounted on the flange of the core bed plate sleeve.

The installation of the newly designed bottom core plate with its sampling tubes leading out of the pressure vessel to a 37-way selector valve has increased in difficulty but a scheme has been worked out whereby the bottom plate with the fixed spike inserts will be installed with stub-piping already attached and then welded up inside, access being from the manhole at the bottom of the reactor vessel. A mock-up has already been made of the area to check that this is a practicable proposition.

The actual fuel for the first experiments has yet to be determined. It will be remembered that one proposition has been to load the fuel boxes with green thorium and uranium/carbon compacts so that carburization takes place within the reactor. Up to 5% volume change can however take place and may result in the fuel boxes being split unless proper allowance has been made. It has been necessary in any case to build a facility capable of making complete sintered carbide fuel pellets and it is probable that in spite of the handling difficulties these will be used for the first charge. Should the technique

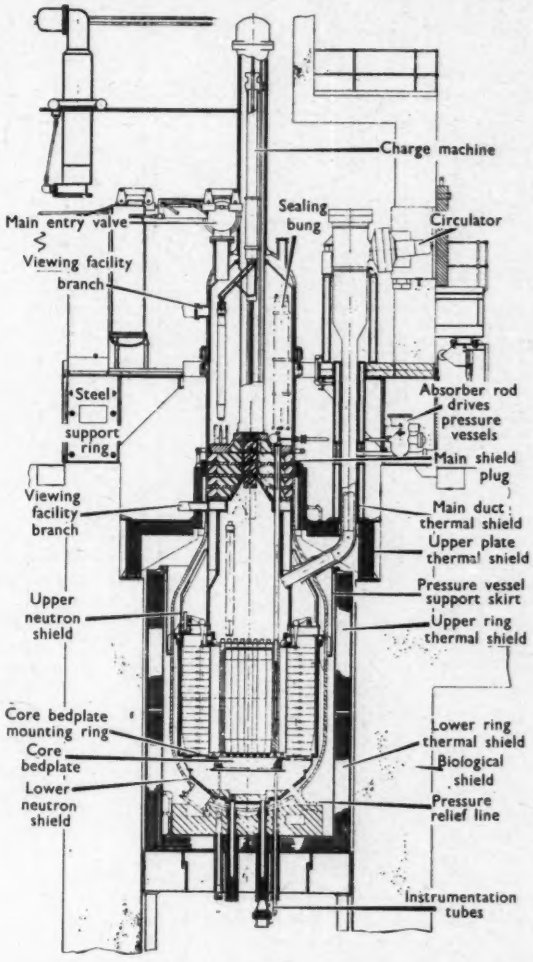
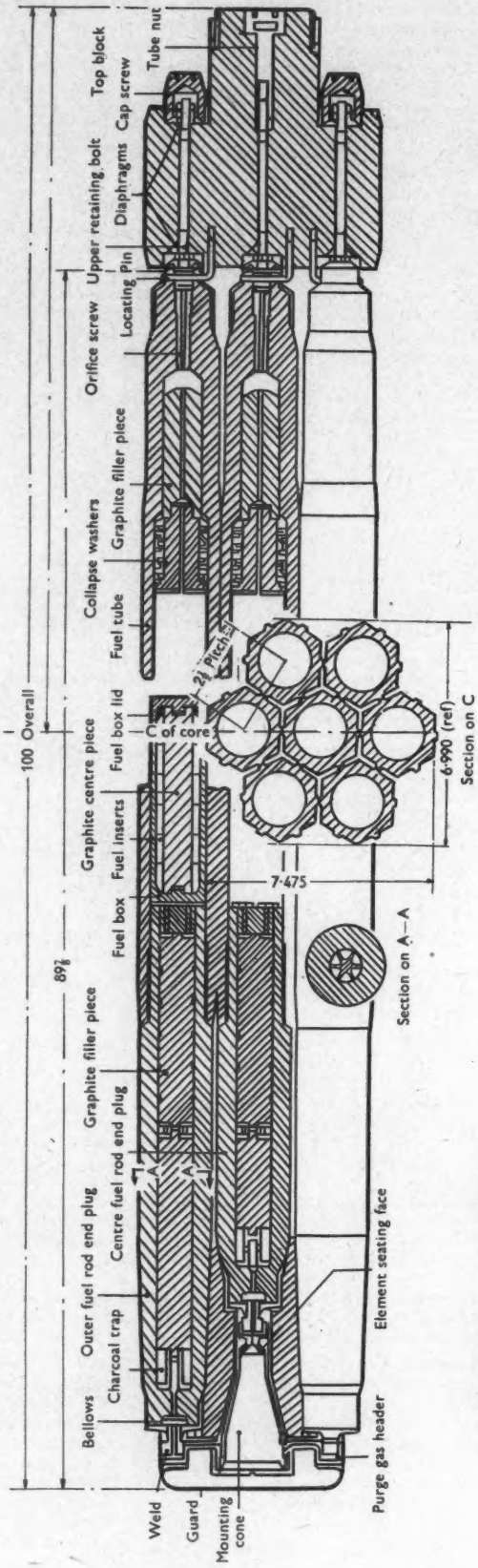


Fig. 2.—Cross-section through Dragon reactor.



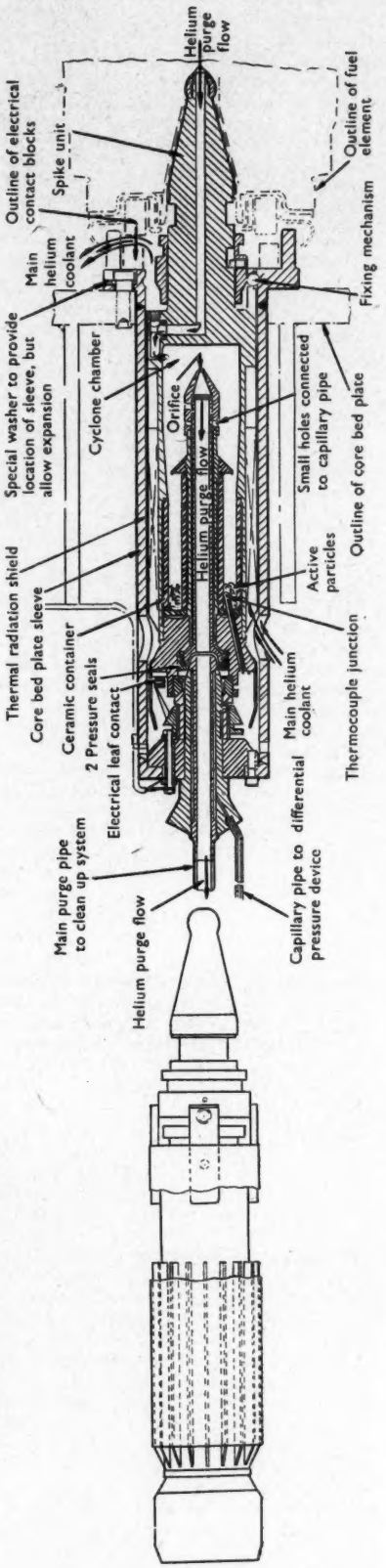


Fig. 3.—Vertical cross section of fuel element with, inset, a plan section of a complete 7 rod cluster. Recent modifications include the provision of a metal strap at the top. Dimensions are in inches.

Fig. 4.—Cross section of a mounting spike together with an outside view. This component which now incorporates a cyclone and sampling system is arranged to be removable from the core bed plate by means of the charge machine.

of coated particles be adequately advanced then these would be used but it is unlikely that sufficient experience will have been gained in time.

Core Components

Although physics experiments on Zenith have indicated that the absorber rods will be some 50% more efficient than the original calculations indicated it has nevertheless been decided to increase the control rod length from 5 ft to 5 ft 11 in. To permit this the shock absorber has been removed from the lower end of the control rod to a fixed position in the base of the live reflector block. The speed of the rod has also been reduced.

Providing a seal between the inlet and outlet gases and a suitable unclamping mechanism for the core is a difficult operation and a number of designs have been investigated. For the seal it has now been decided to use a graphite dumb-bell. This bridges a gap between the graphite columns around the core and the metal structure of the hot box. It is enclosed in a metal envelope to maintain the seal should there be a fracture of the graphite part.

The unclamping device consists of a series of bellows operated plungers, pressure being applied when it is required to open out the boundary blocks. The main shield plug has also been changed to a laminated steel and graphite structure in place of the concrete-filled steel structure which has been discarded because of the degassing problem with concrete.

Heat Exchangers

It is only in the past 12 months that final decisions have been taken on the heat exchangers, and it has been concluded that a boiling water evaporating system with forced circulation is the most advantageous as, by designing it with a low pressure drop, shut-down heat can be removed by natural circulation of the steam-water mixture should a circulating pump fail. The design, however, follows closely the previously indicated pattern; the evaporator consists of 63 tubes of 0·55 in bore wound in a series of coaxial coils with the water entering at the bottom. Each set of coils is equally spaced in an annulus formed by a central by-pass duct and an outer ring of down-comer tubes. There are seven coils containing, respectively, 6, 7, 8, 9, 10, 11 and 12 tubes; under design operating conditions the quality of steam at outlet will be 16·4%. The by-pass valve uses a vernier motor as do the control rod drives, a system of torque limitation ensuring that the motor cannot drive beyond its allowed range of travel.

When it is required to isolate a heat-exchanger loop, an additional power supply produces the excess torque necessary to lift the by-pass valve past its torque restrictor to its isolation position, where it is mechanically held until a similar high torque reverse drive is applied to return the valve to its normal position.

Fission Products and Helium Purification Plant

Continuously removing the fission products and purifying the coolant gas are critical aspects of the reactor system. A great deal of work has been done on the purities that are necessary and which can be achieved and in determining the most efficient means of trapping the various fission products. A small flow of helium is drawn from the primary cooling circuit via the interior of the graphite fuel element cans but provision is made also for a second stream directly from the primary circuit to be used during initial clean-up processes and the like. Initial filtration takes place, as explained above, in the fuel assemblies after which the purge stream passes into a common purge gas manifold and then through a treatment plant where the following processes occur.

1. The volatile fission products are condensed out and the purge stream cooled to a temperature of $<100°C$.
2. Any remaining fission products—iodine and bromide—are trapped out.
3. Hold-up of the xenon and krypton in water-cooled charcoal beds to allow them to decay.
4. Impurity gases such as CO, H_2 and CH_4 are oxidized to water and CO_2.
5. H_2O and CO_2 trapped out by freezing on cold surfaces.
6. Further delay of the residual xenon and krypton in a liquid-nitrogen cooled charcoal bed.
7. Final trapping of the remaining xenon, krypton and non-oxidizable impurity gases in a regeneratable charcoal trap at $-196°C$.
8. Warming up of the cleaned helium and returning it to the reactor by means of suitable purge gas circulators.

Plant for carrying out steps 4 to 7 inclusive is triplicated and when a feed is taken direct from the primary circuit it is taken straight into stage four.

The main innovations in the past 12 months are the introduction of the oxidation process and the omission of any attempt to separate the staple and long-lived krypton and xenon isotopes from the non-oxidizable impurities for final disposal. Fig. 5 shows the pilot plant which was set up to examine the process and in Table 1 are recorded the results on this plant alongside the design specification for the reactor system.

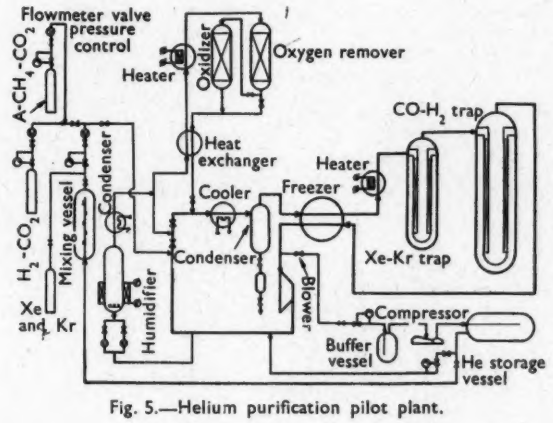


Fig. 5.—Helium purification pilot plant.

Table 1—Performance of gas treatment pilot plant

Gas	Reactor tolerated, vpm	Pilot plant introduced, vpm	Pilot plant residual, vpm
Oxygen	0·001–0·01	—	—
Carbon dioxide	5– 10	1–100	1
Water vapour	5– 10	5–500	1
Carbon monoxide	0–100	2–200	10
Methane	0–100	5–500	1
Hydrogen	0–100	2–200	10
Argon	—	1–100	10
Xenon	—	0·1– 10	10^{-4}
Krypton	—	0·01– 1	10^{-4}

The helium flow rate is 28·4 kg/h and its pressure is 20 atm.

RESEARCH AND DEVELOPMENT

In terms of component development the production of efficient reliable circulators is probably the most critical. Originally it had been envisaged that the Dragon team would develop a circulator but this idea has now been abandoned in favour of development by Brown Boveri in close co-operation with the project. Although a fair amount of experience has now been obtained on gas bearings operating in air and at atmospheric pressure, operation in helium at 20 atmospheres is a relatively new departure, and a number of problems, not altogether unexpected, have shown up. A series of experimental test rigs has been built to settle these problems including representative full-scale models which will be tested under simulated reactor conditions. Before delivery to Winfrith the prototype will undergo a full test programme and at Winfrith it will then undergo rigorous endurance testing.

Possibly of significance to the circulator development but of more general application is the work that is being done on bearing surfaces required to operate in dry helium. During research on this subject, at first concerned primarily with gear trains, it was found that the best unlubricated surface was a nitrided steel and in many cases without further treatment the resistance to wear would be adequate. However, by applying a very fine shot blasting to the surface (sufficient to remove the

bloom and no more) and wiping over with MoS_2 the wear is considerably reduced; indeed the life of components so treated will be a great deal longer than the minimum that could be tolerated. In the same line of work, experiments have been undertaken to determine the best type of ball bearings. Among these satisfactory performance has been obtained with standard EN31 bearing steels fitted with pressed steel cages but they can be improved and in this case by a mild acid etching followed by running in a molybdenum disulphide suspension.

MASS TRANSFER AND FISSION PRODUCT DIFFUSION

From the point of view of the reactor system as opposed to the actual hardware, the major concern is with the carbon mass transfer problem. The rate will depend upon chemical factors and engineering features and is not confined simply to spalling of the core and deposition elsewhere in the circuit but also with the possible deposition on critical structures leading to a breakdown in physical properties. For example, carbon deposition in ceramic materials giving rise to complete destruction has been noticed. Furthermore, fission products may act as catalysts in various reactions. Initially it was expected that the problem would be examined principally in the mass transfer loop rented from the U.K.AEA but delays in the construction of this and a reconsideration of the experimental programme has led to the fabrication of a number of smaller loops with which the problem can be reviewed over a wide range of environmental conditions.

The second most recalcitrant problem is likely to be the diffusion of fission products and the escape and diffusion into various parts of the plant. Estimates of the porosity of fuel box walls indicates that the hold-up time is liable to be of the order of one hour. Within the fuel box with the cold pressed fuel inserts, between 10% and 50% of the maximum possible xenon content is expected to be retained. Those fission products which do leak through the fuel sleeve to the primary circuit are likely to deposit in the heat exchangers and blowers but a stream of 10 l/s, by-passing the core for venting and cooling purposes, would deposit not more than 5 to 10 curies of long-lived activity.

Physics

Physics experiments have continued in Zenith and much valuable data have been obtained and in particular the theoretical predictions have been checked against practical results. In the main, the discrepancies, apart from the control rod evaluation, have not been large. Temperature coefficients have also been evaluated: the core end reflector figures are found to be -6.4×10^{-5}/°C while the radial coefficient is dependent upon the number of control rods inserted. With 5 rods inserted and a poisoned core it was $+3 \times 10^{-5}$/°C and with 9 rods $+1 \times 10^{-5}$/°C. A value of the prompt neutron lifetime of approximately 0.5 ms has been derived from fine rod oscillator experiments which is in close agreement with perturbation experiments with a copper sample.

Graphite

A great deal of work has gone into the evaluation of the behaviour of different types of graphite and the development of improved quality materials. The rapid diffusion of Ba, Si and Cs through graphite is an uncomfortable property but more embarrassing may be the ability of Cs to cause swelling when the temperature is between 350 and 400°C. Thermal cycling may further increase the damage. Impregnation does not seem to be the panacea that it once appeared and considerable attention has been given to the production of new graphites from either a graphite/carbon black/pitch composition or a coke/carbon black/pitch mixture. A further snag with impregnation is that dimensional changes can occur which may require machining after impregnation when tolerances are tight.

Work on the purification of graphite indicates that such a process may be worth while from a chemical reactivity point of view even if not from a cross section. In Table 2 are reproduced some results of Péchiney showing how remarkably pure graphite can be produced.

Table 2—Effect of purification process on graphite contaminants

Sample	Ash, ppm	Iron, ppm	Vanadium, ppm	Boron, ppm
(a) Purified	176	15	47	0·15
(b) Purified	186	10	52	0·15
(c) Untreated ..	1,000	138	9	8·00
(d) Untreated ..	1,080	89	18	6·00
(e) Untreated ..	970	41	9	7·00

Fig. 4.—Fabrication of the Dragon reactor pressure vessel.

Irradiation experiments

The Dragon project has the great advantage of not only being able, but feeling a moral compulsion to enlist the services of a large number of irradiation facilities. At Risø in Denmark burn-up tests are to be made in DR 3. In the first test starting next May, a tube representing the fuel rod tube in which are mounted three full-scale fuel boxes will occupy a fuel element space. Ratings of 70W/cm³ will be achieved at a temperature of 1 400°C (Dragon is 85 W/cm³ average). Post irradiation examination of the capsules will be carried out by AB Atomenergi at Studsvik in Sweden.

Then in Diorit, in Würenlingen, sets of six capsules, each containing a fuel box, are to be inserted shortly in one of the through holes to prove the fuel element design. These experiments will be based on the rig design studies carried out at this establishment last year.

At Petten, too, a design study has been made by RCN for a fuel irradiation rig to investigate the effect of burn-up fuel inserts. After further investigations a series of irradiations following on the Risø experience will be performed.

Meanwhile at Studsvik AB Atomenergi have demonstrated the feasibility of measuring fission product emission from fuel during exposure in a loop. A rig is now being built and should go into service towards the end of next year. A somewhat similar loop has gone into Pluto at Harwell while at the same establishment in Dido a series of fuel capsule experiments has reached a satisfactory conclusion.

It is at Mol in BR2 that the critical in-pile mass transfer loop is being installed where the effect of irradiation on the oxidation of graphite, the hydrogenation of graphite and carbon deposition will be studied under conditions closely resembling those expected in the Dragon reactor. In fact, the pressure in the rig will be limited to 10 atm so as not to exceed the internal operating pressure of BR2, but this disadvantage should not be material.

Finally mention should be made of the heat transfer experiments on a 7-element bundle being undertaken by the Parsons Research Laboratories, Newcastle, and the close contact established with General Atomic in San Diego.

The R and D programme of Dragon thus bears ample witness of the international character of this project.

France

Broad, self-contained programme; independent approach

ALTHOUGH still not as extensive as the United Kingdom's, if comparisons are made in terms of number of employees engaged on atomic energy development, national turnover or megawatts installed, the French nuclear programme nevertheless is broader in scope than any other in Europe. Also in spite of its commitments to Euratom and its present dependency on outside resources for enriched material the time is not far distant when France will have one of the most self-contained atomic energy complexes in the world, with its own supplies of uranium and thorium, its own enrichment and processing plant and its own multipronged attack on power development, civil marine propulsion and naval propulsion. Such a position is partly the result of geological accident, partly of a traditionally independent approach encouraged by the reluctance of the U.S. and the U.K. to disclose information relating to military matters, but also there remains an unwillingness to accept other people's evaluations. Whilst in other countries such as the United Kingdom the general depression in nuclear engineering following the over-production of fossil fuels has resulted in positive reductions in the scale of development, and although one might expect that with the opening up of the Sahara oilfields and the discovery of natural gas reserves the effect in France would be even more marked, any delays which have occurred in the constructional programme can be traced to technical problems and the opportunity has been taken to widen the scope of attack.

The division of responsibilities has not changed appreciably with the years; the Commissariat à l'Energie Atomique continues its fundamental and prototype development work, whilst EDF concerns itself with power station construction, but there is a steady rise in the contribution that is being made by French industry and not merely in the supply of equipment of standard design and to the design of the CEA and EDF. There is a mounting use of industry as a design and consultancy organization capable of undertaking reactor projects, special equipment design and fabrication and there has been a further extension of the practice of arranging for such essential items of production as uranium concentration, fuel fabrication, fuel element fabrication to be handled by joint CEA/industrial companies. As a result, French industry can claim to have the widest experience of atomic energy development and production techniques of any country in Europe.

TABLE 1.

LIST OF FRENCH NUCLEAR REACTORS IN SERVICE OR UNDER CONSTRUCTION

Name	Location	Start-up	Max. flux, n/cm^2s	Power, kW(th)	TYPE			Power, kW(e)	Object
					Fuel	Moderator	Coolant		
RESEARCH AND TEST REACTORS									
EL 1 (Zoe)	Fontenay-aux-Roses	15.12.48	10^{12}	150	Natural U	D_2O	D_2O		Research
EL 2	Saclay	21.10.52	10^{13}	2 500	Natural U	D_2O	CO_2		Research and isotope production
EL 3	Saclay	4.7.57	10^{14}	17 500	Slightly enriched U	D_2O	D_2O		Research, materials testing, isotope production
MELUSINE	Grenoble	1.7.58	10^{12}	1 200	Enriched U	H_2O pool	H_2O		Research
TRITON	Fontenay-aux-Roses	30.6.59	10^{13}	1 200	Enriched U	H_2O pool	H_2O		Shielding studies
MINERVE	Fontenay-aux-Roses	29.9.59	10^{11}	Weak	Enriched U	H_2O pool	None		Purity testing
ULYSSE	Saclay	1961	10^{13}	100	Enriched U	H_2O	H_2O		Teaching (INSTN)
PEGASE	Cadarache	1963	10^{14}	30 000	Enriched U	H_2O	H_2O		Fuel tests for gas cooled piles
SILOE	Grenoble	1963	8×10^{13}	10 000	Enriched U	H_2O pool	H_2O		Research
CRITICAL EXPERIMENTS									
AQUILON	Saclay	11.8.56	10^{7}	Weak	Natural U	D_2O	None		Lattice studies
PROSERPINE	Saclay	17.3.58	5×10^{7}	Weak	Various	H_2O and BeO	None		Critical studies
ALIZE	Saclay	18.6.59	5×10^{7}	Weak	Enriched U	H_2O	None		Lattice studies
RUBEOLE	Saclay	3.7.59	10^{8}	Weak	Enriched UO_2	BeO	None		Lattice studies
MARIUS	Marcoule	7.1.60	10^{8}	0·1	Natural or enriched U	Graphite	None		Lattice studies
PEGGY	Saclay (Cadarache)	2.2.61	5×10^{9}	Weak	Enriched U	H_2O	None		Critical model of Pégase
AZUR	Cadarache	End 1961			Enriched U	H_2O	None		Critical model of submarine prototype
RACHEL		April 1961		Weak	Pu	None	None		Fast neutron study
EXPERIMENTAL REACTORS									
RAPSODIE	Cadarache	1963		10 000	Enriched Pu and U	None	Sodium		Fast neutron breeder
Land prototype for submarine propulsion	Cadarache				Enriched U	H_2O	H_2O		Experiment submarine propulsion
EL 4	Monts d'Arrée (Finistère)	1964		260 000	UO_2	D_2O	CO_2	80 000	Electricity production
PRODUCTION REACTORS									
G 1	Marcoule	7.1.56	5×10^{13}	40 000	Natural U, 100 t	Graphite, 1 200 t	Air, atm. pressure	5 000	Plutonium production
G 2	Marcoule	21.7.58	$2{\cdot}5\times10^{13}$	200 000	Natural U, 150 t	Graphite 1 200 t	CO_2 15 kg/cm²	28 000	Electricity and plutonium production
G 3	Marcoule	11.6.59	$4{\cdot}5\times10^{13}$	200 000	Natural U, 150 t	Graphite	CO_2 15 kg/cm²	28 000	Electricity and plutonium production
EDF 1	Chinon	1962	$4{\cdot}5\times10^{13}$	300 000	Natural U, 150 t	Graphite	CO_2 25 kg/cm²	60 000	Electricity production
EDF 2	Chinon	1963		700 000	Natural U, 250 t	Graphite	CO_2 26·5 kg/cm²	170 000	Electricity production
EDF 3	Chinon	1965		1 200 000	Natural U	Graphite	CO_2 25 kg/cm²	375 000	Electricity production

Materials

Uranium production in France during 1960 amounted to 1 068 t of metal equivalent. This is expected to rise to 1 600 t per annum by 1962 and production will be held at this level for a number of years. Private prospecting for uranium is somewhat less popular a pastime than was the case a few years ago but the CEA is keen to locate further deposits in order to cater for the surge in demand that is anticipated after 1970. The majority of the production is at Malvési (run by the Société de Raffinage de l'Uranium) with roughly 620 ton/a and Le Bouchet where some 410 ton of uranium metal was produced last year. A considerable amount of development has gone into the purification processes and new fluorination plant has gone into Le Bouchet with a capacity of 800 ton/a and a new plant also for the production of metal by magnesium reduction with a capacity of 200 ton/a.

At Le Bouchet also the Madagascar uranium/thorium ores are treated and 1960 yielded 200 ton of thorium nitrate and 58 ton of uranium. The capacity of the plant is in excess of this but certain difficulties were found in the start-up of the Sotrassum plant (joint CEA/Péchiney enterprise) but the initial target of 35 ton per month of monazite has now been achieved. Again at Le Bouchet plant has been installed for the recovery of enriched uranium from scrap and, from treating scrap from EL 3 element production last year, 2 ton of 1·6% uranium was recovered.

Fuel fabrication plants are located at Bonneuil, Saclay and Le Bouchet, all near Paris, principally to serve the needs of the CEA's reactors and, additionally, just outside Saclay a pilot plant has been set up at Corbeville and run by CICAF (a subsidiary of CSF, see *Nuclear Engineering*, March, 1959, p. 129) for the production of sintered oxide pellets. Last year this particular plant produced 12 ton of oxide pellets and has also completed a study on the process to be adopted for the manufacture of the pellets for EL 4 in both natural and enriched uranium to produce a density of between 10·4 and 10·6 g/cm³. The main fabrication plant for the production of fuel elements for the natural uranium programme at present is at Annecy under the control of the Société Industrielle des Combustibles Nucléaires but a second plant is to be built in the Rhone valley at Romans (Isère) by La Compagnie pour l'Etude de la Réalisations de Combustibles Atomiques (CERCA). At one time an alternative site at Saint Loubes, near Bordeaux, was favoured but finally rejected in favour of Romans. The main source of cans for the fuel elements is the company Tréfileries et Laminoirs du Havre.

At Marcoule over the past 18 months a considerable amount of alteration has been made to the extraction plant phased in with batch runs on the elements irradiated in the G 2 and G 3 reactors now operating with a reasonably high utilization factor. The main purpose of the alterations has been to improve the efficiency of the extraction plant whilst at the same time reducing corrosion and improving the shielding of certain sections which has been found inadequate under certain special treatment conditions. The plutonium extraction plant at Marcoule is to be supplemented by a similar plant at Cap de la Hague, construction of which should begin next year. Unlike Britain, France is also participating in the Eurochemic joint fuel element treatment plant at Mol and French industry has taken a leading role in its design and construction.

In view of the EL 4 project in which zircalloy pressure tubes will be used, not to mention the submarine project which presumably will use zircalloy fuel elements and in-core support features, the capacity of the zirconium production industry has been built up. At the Cuise-la-Motte plant run by Nobel Bozel 86 ton of hafnium-free zirconium have already been produced and the process has been improved to the point where the cost of this last purification stage has been halved. At the same time high quality hafnium is also being extracted which may have significance in later control rod designs. Zirconium sponge comes from the works of Clavaux de la Société d'Electrochimie d'Ugine, whereas development of the EL 4 pressure tubes is being handled by CEFILAC.

Also as part of the EL 4 programme but of possible importance should an advanced gas-cooled reactor again be contemplated in France, the development of beryllium components is continuing, notably by Péchiney. The same problems and slow approach to a satisfactory solution are experienced there as in the U.K. It should be noted that the first core for EL 4 is quite likely to be stainless steel canned (see Table 2).

TABLE 2. SUMMARY OF DATA FOR EL 4

Reactor type	heavy-water moderated; gas cooled horizontal pressure-tube
Power	84 MW(e)
Fuel	natural or enriched uranium oxide
Coolant	pressurized CO_2
Fuelling	bidirectional push-through, reactor on load
Control	vertical absorbing rods
Beryllium Canned Fuel	
Bundle of 19 elements	
Natural uranium-oxide	—
Diameter of pellets	13 mm
Thickness of cladding	1 mm
Cross section of UO_2	25·2 cm²
Nominal maximum temperature of cladding	600°C
Stainless Steel Fuel	
Bundle of 19 elements	
Enriched uranium oxide	1·25%
Diameter of pellets	11 mm
Thickness of cladding	0·4 mm
Equivalent thickness (with structures)	0·5 mm
Cross section of UO_2	18·0 cm²
Thickness of graphite sleeves	5 mm
Nominal maximum temperature of cladding	630°C
External diameter of pressure tube	110 mm
Thickness of pressure tube	3·5 m
Thickness of insulation and liner tube	6 mm
Internal diameter of liner tube	91 mm
Lattice pitch (square)	230 mm
Number of cells	216
Active radius of core	191 cm
Active length of core	400 cm
Radial thickness of reflector	49 cm
Axial thickness of reflector	30 cm
Internal diameter of the tank	480 cm
Length of heavy water in the tank	460 cm
Weight of UO_2 (natural)	20·9 t
Weight of contained uranium	18·4 t
Weight of heavy water in the core	41 t
Weight of heavy water in the reflector	40 t
Gas pressure	847 psi
Inlet temperature	260°C
Outlet temperature	500°C
Nominal specific power (across hottest section)	250 W/cm²
Nominal max $\int kd\theta$	28·4 W/cm
Avg/max flux axial	0·71
Avg/max flux radial (without flattening)	0·63
Average specific power in uranium (without flattening)	12·2 MW/t
Thermal power in uranium (without flattening)	225 MW
Net efficiency (vs power in uranium) (without flattening)	32%
Net station output (without flattening)	72 MW
Geometrical buckling	1·46 m²
Initial reactivity excess	~2%
Average fuel burn-up	6 500 MWd/t

It is still undetermined how far France is prepared to go in the production of heavy water in the light of the ample supplies available from the United States (it is of course more in the nature of capital plant than a consumable product such as fuel) and in fact the pilot plant for the production of heavy water and certain specialized pure derivatives for the bubble chamber has been shut down. This plant operating on the distillation of liquid hydrogen located at Toulouse and run by CFEL will not be scrapped as economic studies have indicated that as a polishing system for obtaining high purity heavy water the process is probably the most economic and satisfactory. The plant may therefore be recommissioned as a last stage process should a pilot plant be built working on another system. The CEA in collaboration with Houillères du Bassin du Nord et du Pas-de-Calais and other partners is investigating the ammonia/hydrogen route as a possible by-product process and the CEA in conjunction with Société pour l'Obtention du Deuterium is investigating the H_2S, H_2O reaction with a view to constructing a pilot plant.

Radioisotopes shipped last year numbered 10 000 of which nearly 2 000 went abroad, the gross figure is to be compared with 7 247 for 1959. In terms of value, the income derived was of the order NF 1·6 million of which 40% was exports.

Research and Development

The extensive programme of research and development of the CEA has necessitated a steady increase in staff over the years and a steady rise in budgetary demands. Expenditure for 1960 totalled NF 1 099 million plus NF 420 million for specifically military exercises as compared with NF 847 million in 1959 and NF 778 million in 1957. The CEA employs roughly

TABLE 3—The Nuclear Power Stations of Electricité de France.

PARAMETERS	EDF I	EDF II	EDF III
Reactor thermal power	300 MW	791 MW	1 200 MW
Generator power rating	82 MW	2×115/125 MW	2×280 MW
Net electrical power	68 MW	200 MW	375 MW*
No. of heat exchanger elements	120	4×24	
Grid voltage	90 kV	225 kV	
Containment shell	Gas-tight self-supporting sphere 180 ft dia.		
Reactor fuel	U–0·5 w/o Mo	U–1·5 w/o Mo	
Weight	138 t	250 t	
No. of fuel elements	17 000	23 724	
Fuel element length	2 ft	2 ft	
Fuel element dia. (uranium)	14–35 mm (hollow rods)	18–40 (hollow rods)	
Graphite sleeve dia.		133–103 mm	
Cladding	Mg alloy with longitudinal fins	Mg alloy with polyzonal helical fins	Mg alloy with chevron fins
Maximum flux at centre	3×10^{13} n/cm²s	3×10^{13} n/cm²s	
Reactor moderator	Graphite	Graphite	Graphite
Active cylinder length	30 ft	24 ft	30 ft
Active cylinder dia.	27 ft	40 ft	46 ft
Reflector thickness	2 ft	3 ft	3 ft
Lattice	(Double) square, saturated in the centre	Hexagonal	Hexagonal
Lattice pitch	224 mm and 196 mm	225·16 mm	
Channel dia.	84 mm	135 mm	
No. of channels (vertical)	1 148	2 304	2 500
Reactor vessel	33 ft o.d. × 75 ft	60 ft i.d.	60 ft i.d. × 67 ft
Material	AMMO (Marrel) steel	AMMO (Marrel) steel	Concrete
Wall thickness	107 mm	95 mm	16 ft
Dome thickness	59 mm		22 ft
Weight	690 t	1 321 t	60 000 t
Coolant	CO_2	CO_2	CO_2
Pressure	355 psi	375 psi	355 psi
Wt. of gas	49 t	120 t	
Inlet temperature	145°C	198°C	
Outlet temperature	355°C	365°C	
Gas flow at full load	3 400 lb/s	9 590 lb/s	
Total pressure drop	23 psi	19 psi	
No. of heat exchange elements	120	96	
Characteristics of each element:			
Diameter	2 ft 1 in	3 ft	
Height	94 ft	82 ft	
Total heat surface	3 400 ft²	3 700 ft²	
Pressure drop	2·5 psi	2·8 psi	
No. of blowers	1	4	
Blower power for a flow of	3 500 lb/s: 9·2 MW	2 370 lb/s: 6 MW	
Driven by	2 asynchronous motors	1 asynchronous motor	Steam turbine
Flow control	By rotation of guide blades	By hydraulic coupler	
Full load efficiency	86%	81%	
H.P. steam pressure	310 psi	473 psi	455 psi
Steam flow	633 000 lb/h	421 lb/s	
Temperature	650°F	644°F	707°F
L.P. steam pressure	63 psi	* 127 psi	
Flow	234 900 lb/h	230 lb/s	
Temperature	420°F	644°F	

* With first core.

2 800 staff plus about 12 000 "industrial" workers, the rate of increase amounting to roughly 17% per annum. The largest of the CEA's establishments is still Saclay (4 300) followed by Fontenay-aux-Roses (1 100) and Grenoble (700).

The CEA's newest establishment is at Cadarache (Bouches-du-Rhone) where major site work began first in January of last year. Present plans call for three main projects to be handled at this site (although one can expect it to assume an ever-increasing importance in the future complex of the CEA's programme). These are the development of a submarine propulsion unit, the fast reactor development project and also general research into the properties of plutonium. At one time also this establishment was looking after the civilian ship project, an AGR type of reactor concept entitled Pile à Gaz à Haute Performance. When the civil marine project was dropped as such Euratom expressed an interest in continuing the project as a land-based development exercise but negotiations fell through and it can now be regarded as completely abandoned.

Three reactors are at present planned for this site: Pégase, an enriched uranium, water moderated, 30-MW materials testing reactor with eight test loops; Peggy, a critical assembly to determine the physics of the core of Pégase which has initially been built at Saclay but is being moved to Cadarache; and finally Rapsodie the first fast reactor assembly on the continent of Europe. The engineering design of this last is being handled by Hispano Suiza and the Société des Forges et Ateliers du Creusot and work has already begun at Cadarache on its construction.

In Table 1 the principal reactors and critical assemblies operating or under construction in France are listed. A number of these are of long standing but certain modifications have been made over the past year. Aquilon I has been renamed Aquilon II and has been re-engineered by Indatom and Ateliers et Chantiers de Bretagne according to a revised specification provided by the CEA in order to allow greater flexibility in the changing of the core lattice. Its principal function is to provide information on the physics of cores suitable for EL 4 with both oxide and metal fuels and also some work is being done on this reactor for the Orgel project at the request of Euratom.

Proserpine has also been modified. It began operation early this year with a solution core of uranyl sulphate of high enrichment provided by the United States. The experimental programme is somewhat similar to that being carried out at Dounreay on the criticality programme there in which the reactivity of various plutonium mixtures and geometries with and without reflector are studied.

Alize II has been redesigned with the help of Indatom and other French and Belgian companies and has been provided with an inner reactor vessel in which are disposed the fuel boxes made up of plates of highly enriched uranium. The whole unit has been designed to allow rapid and easy changing of the core lattice. Control of the reactor which is run at constant flux level is by mixing boron with the light water moderator. The programme for this reactor will be associated with the Chooz pressurized water reactor and also the ship propulsion project at Cadarache where another light water unit Azure is ready to go into operation.

Rubéole, a beryllium oxide moderated reactor has also been reconstructed to allow greater flexibility of operation and has been in operation in its new guise for most of this year.

Other assemblies which are worthy of note but have received little publicity are the reactor Marius, at Marcoule, which has been financed by EDF, and César, a reactor which is being used for the investigation of hot assemblies. Both of these are concerned with the graphite moderated gas-cooled programme. Mention should also be made of Rachel, a plutonium metal fuelled reactor which went into operation this year and is used to study the physics of fast breeding systems. In

connection with the fast reactor programme, industry is assisting in the development of heat transport systems, sodium heat transfer being investigated in a 1 000 kW rig engineered by Le Groupement Atomique Alsacienne-Atlantique who is also to bring into operation a 5 000 kW rig.

EL 2 has also been rejuvenated and provided with a new control system and is now fuelled with elements of a uranium chromium alloy containing 0·01 w/o Cr. During the past year EL 3 had its power raised to 17·5 MW following an augmentation of the heat removal system. Fuel elements for this reactor are highly enriched and have been regularly running up to 10 000 MWd/t. A new element is, however, in course of development which is of a snow crystal cross-section.

At Saclay a university reactor Ulysse, built for l'Institut National des Sciences Techniques Nucléaires and also to serve as a university prototype has gone to full power this month. It is a 100 kW pool type reactor using highly enriched uranium and was engineered by Auxiatome. Already this company has received inquiries from Euratom for a similar installation to be put in at Ispra.

The combined CEA-university reactor at Grenoble, Melusine, has been working at maximum capacity and plans are going ahead for a second reactor to be put in, also the swimming pool type, and called Siloé. The plans call for the maximum power of this new plant to be 10 MW provided the heat removal problems can be resolved.

EL 4

The main reactor construction project that the CEA is handling is EL 4 a prototype-cum-experimental reactor of the gas-cooled heavy-water moderated type. The main parameters of the design of this horizontally disposed reactor with a push-through fuel system operating from both ends are listed in Table 2. A site for this reactor has been acquired at Monts d'Arrée in Finistère and construction will begin at the end of this year. From the specification it can be seen that whilst a natural uranium beryllium canned fuel is sought, provision is also made for enriched fuel in stainless steel.

Research has, however, not been confined to these two materials and the initial results on an iron aluminum alloy containing 16 to 35% w/o Al have indicated that this alloy is worth further consideration. In regard to the use of zircaloy a general programme of research is under way which has revealed, for example, that corrosion rates in water of zircaloy-2 are acceptable up to 350°C but hydrogen embrittlement occurs, so that use of zircaloy-4, a nickel-free alloy, has been recommended. Also it has been found that zircaloy-2 in contact with stainless steel under vibrationary conditions corrodes rapidly. As a possible substitute for the relatively cold pressure tubes in EL 4 the behaviour of alloys of magnesium in water at 95°C have been studied and show some promise. Sintered magnesium also cannot yet be ruled out.

THE POWER PROGRAMME

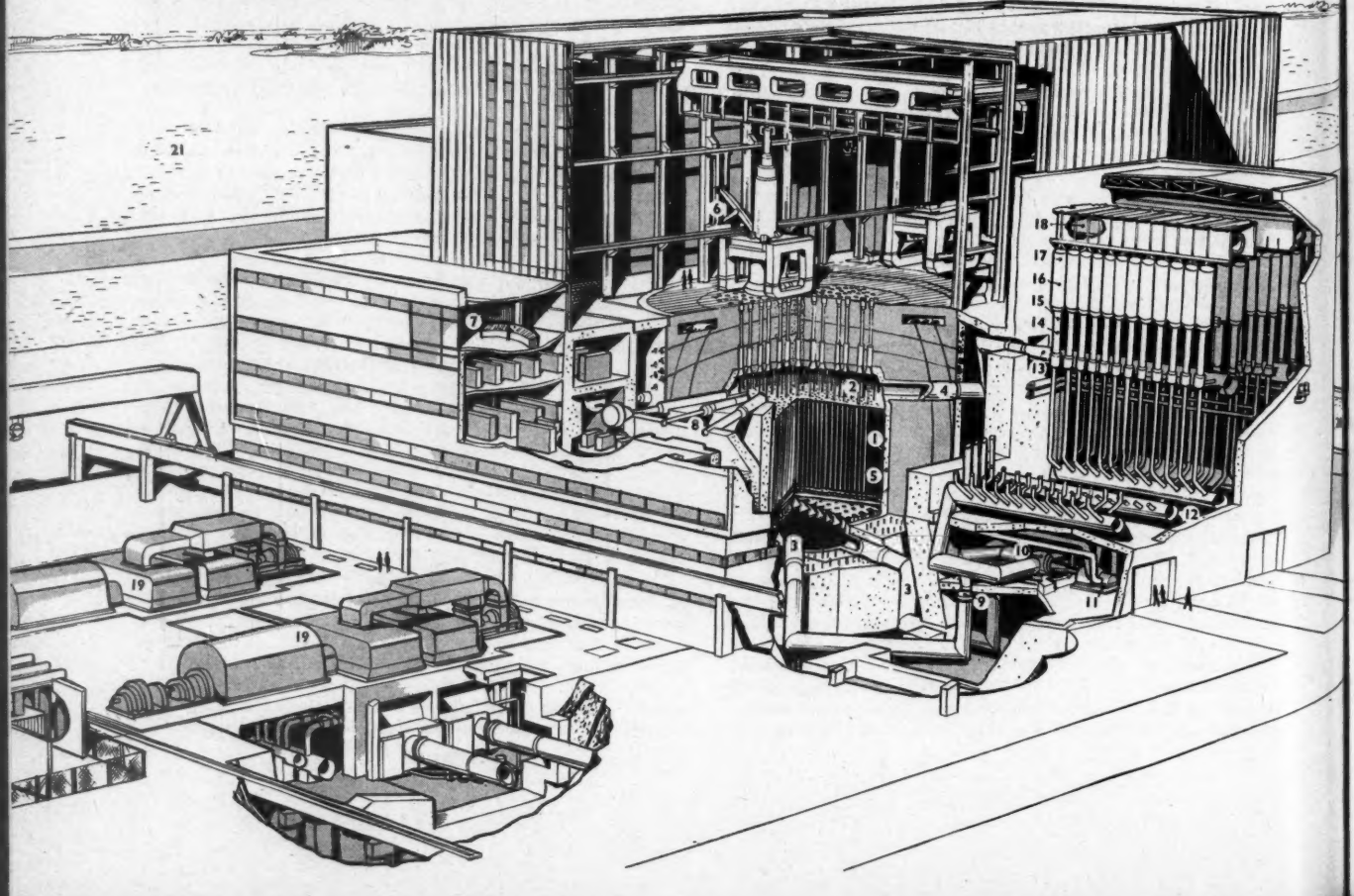
EDF 1

At Chinon one of the major hurdles that had arisen in the power development programme has now been successfully surmounted. The pressure vessel of EDF 1 which cracked catastrophically when first erected and had to be disassembled, the plates re-treated and construction begun again, successfully completed its pressure testing in August. The pressure vessel itself was actually finished in July and during the tests (performed when the majority of workers on the site were away on holiday) the pressure was raised to 600 psi (42 kg/cm²) which is 1½ times the normal operating pressure of the reactor. The test was performed hydraulically with the water at a temperature of 98°C.

An interesting feature of the test was the use of the BSD data processing units for handling the large volume of data produced by the strain gauges and for giving instant read-outs and providing warning levels. The method of testing was to take the vessel to pressure and down to atmospheric in a series of cycles, the peak pressure being increased each time. On all occasions on releasing the pressure no deformation

Fig. 1.—Sectional perspective drawing of EDF 3.

KEY: 1. Sealing membrane. 2. Control rod guide tubes. 3. Reactor CO_2 inlet duct. 4. Reactor CO_2 outlet duct. 5. Thermal insulation. 6. Supplies to charge machine. 7. Control room. 8. BFED tubes. 9. Shut-off valve. 10. Blower. 11. Auxiliary turbine. 12. Heat exchanger CO_2 exit. 13. Heat exchanger CO_2 inlet. 14. Reheater. 15. Superheater. 16. Economizer. 17. Evaporator. 18. Drum. 19. Main turbo-alternators. 20. Cooling pond. 21. River Loire.



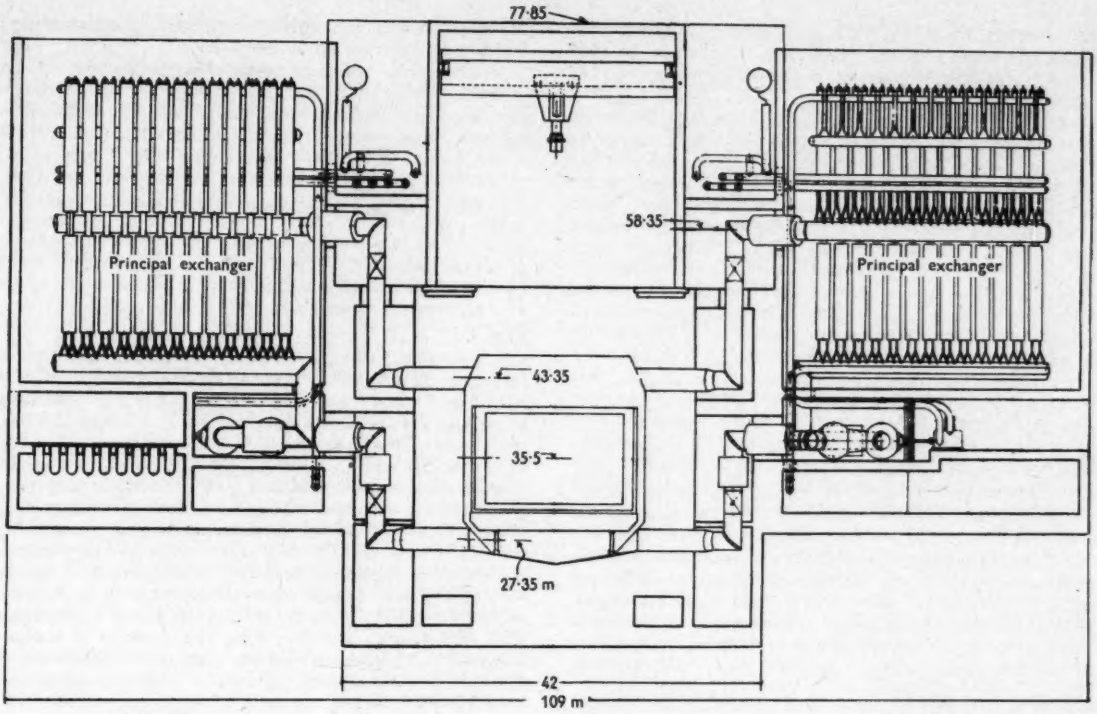


Fig. 3. (Above).—Vertical cross-section of reactor building showing heights (in metres) above datum.

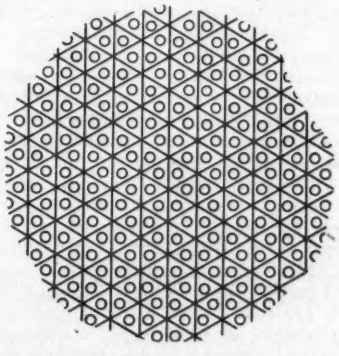
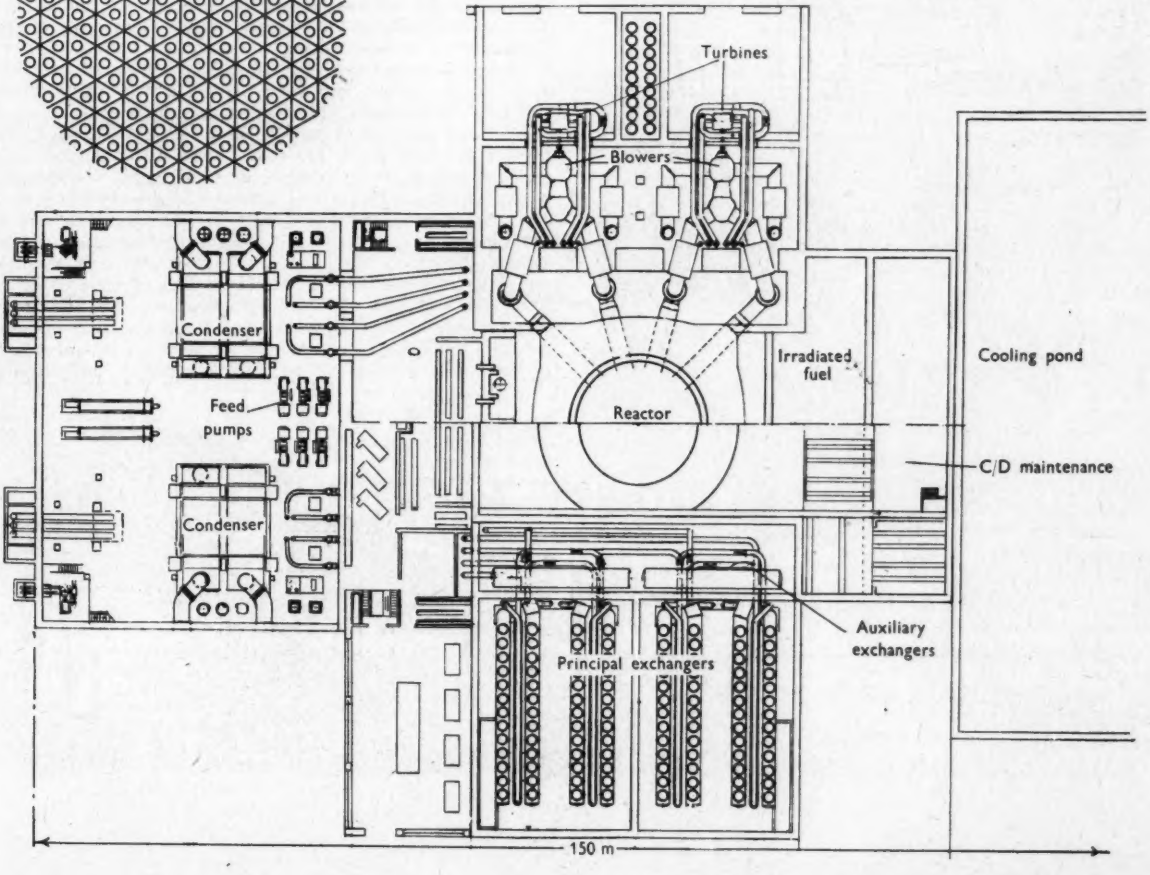


Fig. 2.—EDF 3's triangular lattice of stressing cables.

Fig. 4. (Below).—Plan of EDF 3 reactor; the upper section is at blower level and the lower at charge floor level.



could be detected. It will be remembered that during construction the bottom of the vessel had been stress relieved followed by the bottom plus the first three courses, and then the six and finally including the top dome.

Work is now proceeding on completing the standpipe assembly and the top slab may be ready for pouring by the end of the year. The installation of the charge machine will follow rapidly as the equipment is almost ready in the manufacturer's works. Work on the outside containment vessel had been stopped temporarily after completion of the bottom courses in order to limit the diameter of the building and assist the access problem. It is not anticipated that completion of this vessel will take long in view of the relatively conventional nature of the construction. The long delay in the completion of the reactor vessel has not prevented a number of the components being completely tested. For example, the turbine has been running, the blower has been tested and also the heat exchangers. It should be possible to commence graphite loading in the spring (the stack is of a block and tile construction similar to Bradwell and without sleeves) the materials already being in stock at Chinon and fuel loading may thus begin in the autumn. It is possible, however, that it will be 1963 before the reactor finally comes on load.

EDF 2

EDF 2 should benefit greatly from the experience that has been gained on EDF 1 and indeed evidence of this is already apparent. The steel for the pressure vessel is similar to that of EDF 1 (although to a stricter specification) and to date no troubles have been experienced in welding up the pressure vessel which is complete up to the inlet ducts. Furthermore, the next courses are already on site and the surrounding building is complete up to the roof.

A completely different mode of construction has been adopted with the EDF stations from that adopted in England, there being no Goliath crane and indeed very little provision for heavy lifting gear. The chief lifting equipment for EDF 2 is the reactor crane itself, the gantries having been extended beyond the building so that the reactor crane can pick up from the outside and drop equipment within the biological shield. An unusual feature of EDF 2 also is the decision to build the cooling pond first, which on completion was roofed in with a temporary roof (sections of which could be removed for the lifting out of heavy equipment) and this was equipped as a pressure vessel workshop of very high quality.

EDF 3

Not only because it is the most modern but also because of the decision to adopt a concrete pressure vessel design will EDF 3 be Chinon's most exciting project. In Fig. 1 we are able to publish for the first time a simplified cut-away drawing of the station. It will be seen that the core is vertical and rests in an almost cubical concrete block. There are four main cooling circuits each provided with a circulator driven by a steam turbine and each containing a bank of heat exchangers considerably shorter and more compact than those adopted for EDF 1 and EDF 2. EDF established several months ago a research establishment near Paris to examine heat exchanger designs and heat transfer characteristics and the savings in the design for EDF 3 already more than pay for the research and development put in. The steam cycle is similar to Dungeness, high pressure steam being taken first to the back pressure turbines driving the blowers, reheated and then fed to the T.S.V.

The main parameters of EDF's three stations are shown in Table 3 from where it will be seen that EDF 3 is to be initially a 1 200 MW (thermal) reactor delivering 370 MW of electricity, but it is to be provided with two turbine generators of 280 MW each, to provide for a significant raising of the rating in the years to come. The critical feature of the concrete pressure vessel design concerns the anchor heads at the end of the cables. It will be remembered that in the G 2/G 3 reactors these are massive concrete bobbins and fitting these in on a systematic basis was difficult.

Anchors have now been developed, however, which are only 12 in approx. across, and have built-in a 4-in screw which will take the load and which will automatically take up slack as the heads are jacked out. These are attached to cables of smaller diameter which are much more easily handled and arrive on site on drums as might electrical cables. The pattern of pre-stressing in the top and bottom is on a triangular pattern (Fig. 2) there being three groups of cables at 120° which form a triangular pattern. In the centre of the triangle will be located the access tubes for control rods and fuel channels and from each standpipe it will be possible to serve either 32 or 36 fuel channels. In the longitudinal direction and hence surrounding the core the cables are roughly vertical but disposed in a barrel shape to provide the necessary inward pull.

The complete vessel can be poured before any pre-stressing

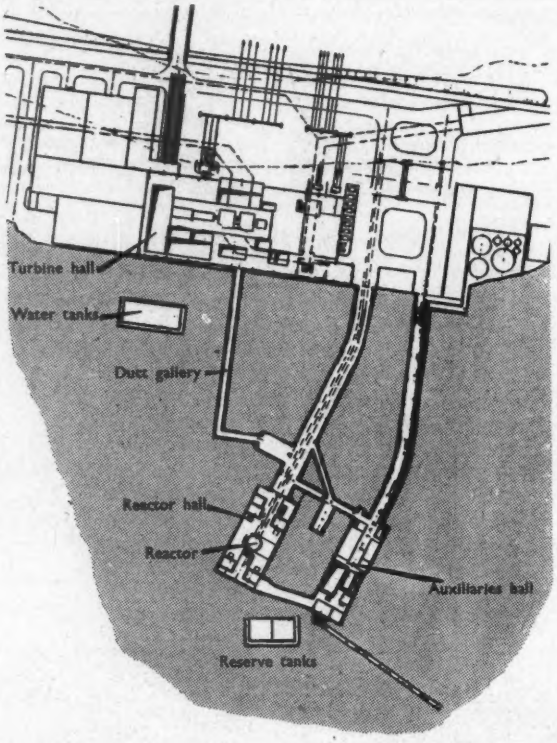
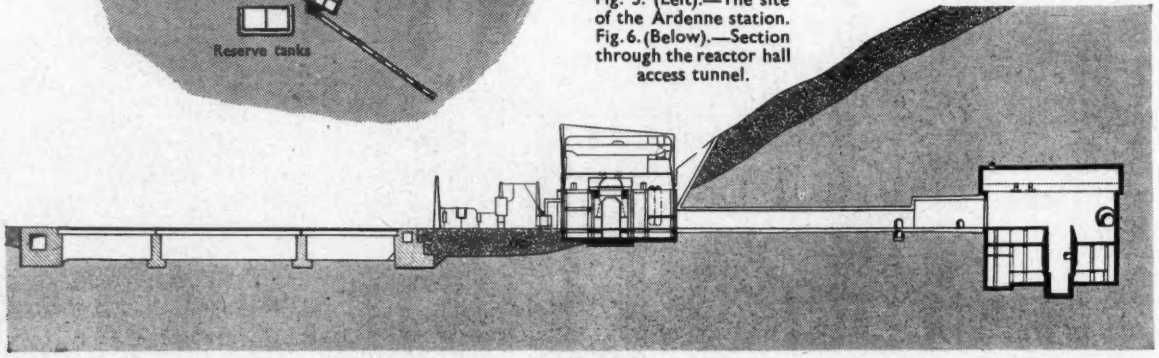


Fig. 5. (Left).—The site of the Ardenne station.
Fig. 6. (Below).—Section through the reactor hall access tunnel.



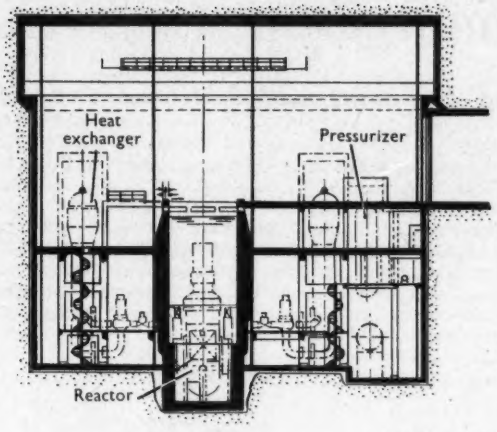


Fig. 7. — Cross-section through the 37 m high Chooz reactor building.

is attempted and work has already begun on this task. The foundations are laid and the majority of the bottom end is already in position. To prove the design three models on a one-sixth scale were built and were pre-stressed using the same cables and heads and tensions as are planned for the Chinon vessel but at six times the pitch. Stress concentrations were therefore exaggerated and the behaviour of the cables and heads themselves could be tested as well as the overall design of the vessel. It has not been found possible to burst the vessels and these models have been tested up to 1 200 psi which is four times the operating pressure without any cable breaking or any pieces of concrete breaking away. At these very high pressures, gaps have certainly been opened in the concrete but these have closed on taking the pressure off and there seems to be no permanent damage whatsoever.

It will be some time before we are able to give details of the sealing techniques to be adopted and the provisions made for expansion, cooling, screening and the like, but these model tests have already proved that as regards the bulk pressure, the design is capable of doing much more than it will be called upon to do.

The Ardennes Station

Negotiations over the Franco/Belgian project for a PWR power station at Chooz on the France/Belgium border with Westinghouse and French and Belgium companies were concluded on September 25 with the signing of the SENA contract. The agreement is actually made under French law and the power station will be built on French ground and will be controlled by the Société d'Energie Nucléaire Franco-Belge des Ardennes. It is 50% French and 50% Belgian owned, the French contribution coming from EDF and the Belgian contribution from a group of five Belgian companies called Centre et Sud.

TABLE 4
ARDENNES PWR (CHOOZ)

Power output	825 MW(th) 258 MW(e)
Net output	242 MW(e)
Station efficiency	29·3%
Fuel	3·1% enriched UO_2 in s.s.
Total weight	45 t
No. of fuel elements	120
Mean burn-up	14 700 MWd/t
Primary system pressure	2 145 psia
Inlet temperature	267°C
Outlet temperature	300°C
No. of coolant loops	4
Duct diameter	600 mm
Coolant flow	1·5 m³/s
Pressure vessel dimensions	3·2 m i.d. × 12 m
Wall thickness	23 cm in the barrel 12 cm in the bottom 23 cm in the top
Cladding thickness	6 mm
Weight of vessel	250 t
Heat exchanger size	3·5 m o.d. × 12 m
Heat transfer surface/unit	1 400 m²
Pressurizer	1·35 m i.d. × 7·65 m
Heater power	350 kW
Steam pressure at TSV	465 psia
Steam temperature at TSV	237·5°C
Steam flow	1 400 t/h

Westinghouse of America are the prime reactor contractors and the reactor technology will follow closely that of Yankee. Some variations in design have been made; for example, in the control system followers have been added to the rods in order to control more reactivity. It is however in the civil engineering and the disposition of the reactor units that the plant differs most markedly from its predecessors.

The reactor heat exchangers, the auxiliaries and fuel element cooling pond are to be located underground in two chambers to which access is by underground tunnels. (See Figs. 5 and 6.) The turbine house is outside and steam is brought to it via a special duct gallery which can be sealed off in the event of any malfunction of the reactor. The desirability of this approach from the safety angle is obvious and present estimates for the costs indicate that there should be no penalty in comparison with a normal above-ground construction. EDF particularly has considerable experience through its hydro-electric projects in the building of major installations underground in rock and have already gone a long way towards preparing the underground chambers and access galleries.

The reactor is a PWR operating at very high pressure (151 kg/cm²) and is provided with four coolant loops each with its own heat exchanger and the circuit is served by a single pressurizer. In the turbine house a single turbine will generate 258 MW of electricity gross, 242 MW nett. The main plant parameters are given in Table 4.

Nuclear contractors as stated above are Westinghouse, but their associate European companies will undertake the bulk of construction outside the first core. The pressure vessel has been assigned to Société des Forges et Ateliers du Creusot who will also handle the pressurizer and turbine and in association with the Belgian ACEC the primary circuit. ACEC will provide the alternator while heat exchangers and condenser will come from Cockerill-Ougrée.

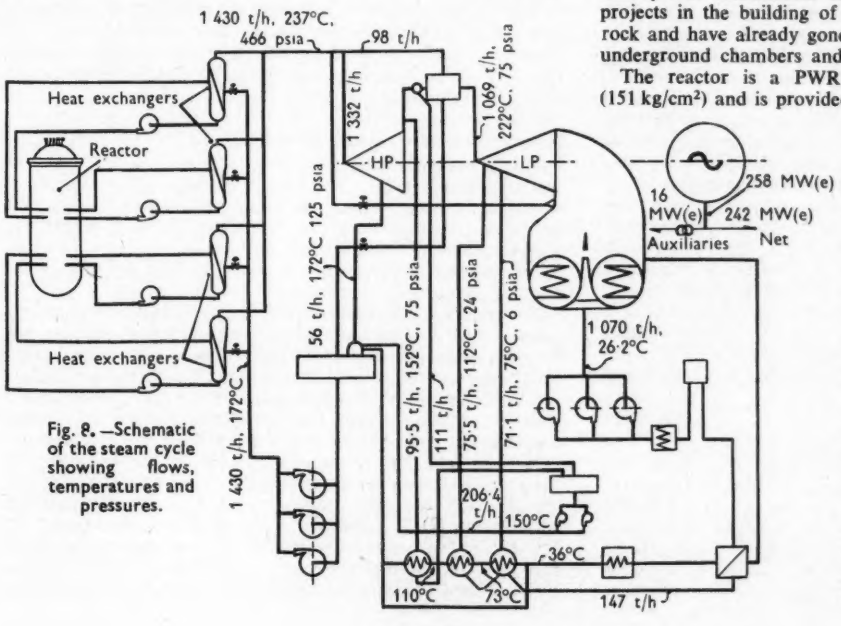


Fig. 8. —Schematic of the steam cycle showing flows, temperatures and pressures.

Patent Law and Procedures

A Review of Euratom and National Practice

ONE of the ways Euratom aims to achieve its objectives of creating "conditions necessary for the speedy establishment of nuclear energy industries" is through the application of special patenting procedures. In both the U.K. and U.S. the exploitation of nuclear energy has been the subject of special patent laws and practice. These were introduced for the purpose of national defence. Later, however, they became used for shaping the policies followed for the industrial development of nuclear energy. These policies have been to entrust responsibility for research and development to national authorities, giving them virtually complete patent control over all basic nuclear technology.

As Euratom aims at a different policy and in view of Britain's negotiations for entry into the Community countries it is opportune to examine the Euratom patent provisions and compare them with the procedures followed in the U.K. and elsewhere. Although none of the other European countries, not even community members, have special nuclear patent legislation, such as found in the U.K. and U.S., some of the national nuclear authorities follow patenting and licensing procedures which are different from those planned by Euratom. And France, of course, has a unique commercial organization established specifically for the handling of nuclear patents.

The principal Euratom patenting provisions are contained in the Rome Treaty under the heading of "Dissemination of Information." They cover the right of any member states or any person or enterprise in those states to make use of Euratom owned patents, the obligation of member states to notify Euratom of all applications for patents or nuclear inventions, and compulsory licensing. The Treaty does not cover ownership of nuclear patents arising from contracts undertaken for Euratom by industry. This is dealt with in a special code of practice which was published earlier this year.

Applications for Use Invited

Under the first Rome Treaty patenting provision Euratom is obliged to make available patents and all information necessary for their exploitation to any member state or person or enterprise thereof who apply for them. Naturally, there are conditions. These consist basically of proof that the applicant can effectively exploit the patent he requires, and treat the information to be acquired as a trade secret. Royalties and the right to sub-licence are subject to separate agreement. If there are any disputes, the issue can be referred to the Community's Court of Justice.

In effect this is a legal invitation to bodies outside Euratom to participate in the exploitation of nuclear energy, a welcome contrast to some of the provisions of atomic law in the U.K. Under the Atomic Energy Act, 1946, the Minister of Supply (his authority is now vested in the Minister for Science) has power to prohibit the acquisition, production, treatment, possession, use, disposal, export or import of, among other things, any plant designed or adapted for the production or use of atomic energy.

When the Atomic Energy Authority was established in 1954 it was given powers to do whatever it considered necessary for forwarding the development of nuclear power. In view of the 1946 Act it was given a virtual monopoly and, as will be shown later, it is on this basis that it has conducted its patenting practice.

Premature Disclosure Required

Whereas the first Rome Treaty patenting provision is welcome and encouraging, the second one appears somewhat unnecessarily intrusive. It requires applications for patents on nuclear inventions to be notified to Euratom headquarters and, if requested, the contents of the application divulged. If the applicant refuses to provide the information himself the state patent office with which he filed the application is obliged to pass it on. The applicant is given three months and the state 18 months from the time the application is filed to do this.

A similar requirement is made for unpublished patent applications which although not specifically nuclear inventions are considered directly connected or essential to the development of nuclear energy. The onus of notification in this case, however, falls on the state patent office, who are given 18 months to do it, and a further two months for divulging the specification.

Precedences in U.K. and U.S.

Not dissimilar provisions occur in both British and U.S. atomic energy law. Under the terms of Section 12 of the Atomic Energy Act, 1946, the Comptroller General of Patents, Designs, and Trade Marks is obliged to submit to the Atomic Energy Office notice of application for patents or inventions relating to the production or use of atomic energy. The Office then decide whether the invention would be of military use. If not, the Patent Office is instructed to proceed with the processing of the application in the usual way.

Ostensibly, the provision is for military purposes, but there is no legal specification that the Atomic Energy Office cannot make any other use of information obtained in this way. Military requirements could, in fact, be met under the terms of the general patent law.

In the U.S. all patent applications for nuclear inventions have to be disclosed by the Patent Office to the AEC, who, unlike Euratom, are under no obligation to treat the information confidentially. Indeed, the Commission can apparently supply unpublished patent applications for privately owned patents to foreign governments, on payment, of course, of suitable compensation!

Euratom, on the other hand, intend to go to considerable trouble in ensuring that unpublished information is kept confidential. The number of people with access to it will be strictly limited and anybody who divulges such information will be subject to claims for damages from the Community. Presumably, the purpose of the information is to provide Euratom with a guide to what exactly is going on in the way of nuclear developments and help them prepare to plan accordingly.

Many lawyers find this provision an unwarrantable departure from normal patenting practice, as they do the similar provisions in English and American law. It certainly seems a debatable point and there may be some wonder as to how it remained in the Rome Treaty.

Possible Step to Common Patent

One answer may be that it is intended to be used as a sort of stepping stone for the Community's eventual introduction of a common European patent. Another may be simply that four of the signatories to the Treaty are countries where patents are granted almost on application! With no search period to worry about the Treaty requirements would have little significance for them.

Also disliked by patent lawyers are provisions for compulsory licensing. Again these are not peculiar to the Rome Treaty, nor for that matter, to nuclear energy. The Treaty provides for such licensing to (1) the Community or any of its joint nuclear research centres and (2) applicants from private, industrial and other undertakings within the Community. In the first case it would appear that the patent owner has little say in the matter except on how much he should be paid in compensation. In the second case certain conditions have to be fulfilled. These are that (1) four years have elapsed since the filing of the application, (2) the utilization of the invention is necessary for the development of nuclear energy, (3) the inventor or patent owner has not satisfied the above need himself or through his licensees, and (4) the applicant for the licence is in a position

to exploit the patent. The owner can also defer the granting of a licence if he can establish good reasons for not having utilized the patent himself.

If there are any disputes arising from compulsory licensing, these can be dealt with, in the first stage, by an Arbitration Committee, in the second, if necessary, by the Court of Justice.

In Britain, compulsory licensing is provided for under the ordinary patent law, as it is, in fact, in most countries. The purpose is to secure exploitation of patents when it is considered necessary for national needs, or, as it is defined in the U.K., for "services of the Crown." This is not necessarily for defence purposes. Quite recently, for instance, this provision was invoked by the Ministry of Health in respect of patents on certain medicines. Even so, it has been considered necessary to give nuclear energy special treatment. Under Section 104 of the Patents Act, 1949, the Minister of Supply (his authority is now vested in the Minister of Science) has power to authorize *any person* to use any patented invention in the production or use of atomic energy. So far as it is known this power has never been used except for the benefit of the Government or the AEA.

Compulsory licensing in atomic energy also gets special treatment in America, under Section 153 of the Atomic Energy Act, 1954. In view of the fact that most U.S. nuclear patents appear to be the property of the AEC and that it is usually almost impossible to prove otherwise, it is not thought that there has been much chance to use this provision.

An eventuality not provided for by the Rome Treaty but covered by U.K. law is the patenting of a nuclear invention in outside territories. Under the Atomic Energy Act, 1946, Section 12 (5), nobody resident in the U.K. can apply without written permission for an overseas patent for a nuclear invention not already patented in the U.K. The purpose of this provision was presumably to prevent an inventor from providing a potential enemy with a warlike nuclear device—a possibility which could be met under the common patent law. Whether it has been invoked for any other reason is not known. Applied to industrial uses of nuclear energy it would, of course, be in direct conflict with the Euratom provisions.

Encouragement to Industry

From even a superficial examination of the Rome Treaty provisions it is obvious that Euratom has no intention of maintaining or supporting restrictive monopolistic patenting policies. At the same time, there is a great awareness of the need to respect as much as possible the accepted rights of individual people and companies. The Treaty goes to great length, for instance, in defining the conditions under which compulsory licensing can be made and what steps grieved parties can take to receive redress.

Further proof of this awareness is shown by the decision to allow patents taken out on work arising from industrial contracts for the Community to become the property of the contracting company, regardless, it would seem, of whether the invention involved is specifically nuclear or otherwise. The Community has royalty-free use of such patents and can grant sub-licences and, of course, under the Treaty provisions require it to be licensed.

If the company does not want to take out a patent, Euratom has the right to do so, the contractor retaining a royalty-free non-exclusive licence, with the right to grant sub-licences under certain conditions.

These provisions are in sharp contrast to the practice followed by most national nuclear authorities in their dealings with industry. In the States, for instance, until modified under the recent AEC Omnibus Act, the law has been such that all specifically nuclear inventions arising from even the slightest of relationships between industry and AEC have become the property of the Commission. It was the cause of a considerable amount of bad feeling from industry and even the present amendment is considered by some as not enough.

Section 152 of the Atomic Energy Act, 1954, now reads "Any invention or discovery, useful in the production or utilization of special nuclear material or atomic energy, made or conceived in the course of or under any contract, subcontract, or arrangement entered into with or for the benefit of the Commission, regardless of whether the contract, subcontract, or arrangement involved the expenditure of funds by the Commission, shall be vested in, and be the property of, the Commission, except that the Commission may waive its claim to any such invention or discovery under such circumstances as the Commission may deem appropriate. . . ." Previously, the section specified that inventions arising from "other relationships with the Commission" should also become the AEC's property and that all inventions were "deemed to have been made or conceived by the Commission."

Naturally enough companies who have contributed to the development of an invention feel that even if they cannot own the titles to the patents they ought to have some preferential treatment as to their use. In the case of specifically nuclear patents, however, even the latter possibility is missing, as under AEC practice patents are available royalty-free to anybody who applies. Certain amendments to the Act now make ownership a little easier and the section which made it possible for the AEC to interfere with licensing arrangements relating to privately owned nuclear patents has been repealed, thus giving industry a slightly freer hand.

Until recently even AEC-owned foreign patents were available royalty-free to anybody. This has been changed so that in countries where the local practice is to charge royalties on patents the U.S. will charge on their patents too, except if the patents are to be used by U.S. citizens or corporations.

Three Classifications

Inventions which are specifically nuclear are classified as type "A" and those which are incidental type "B." A third classification, "C," is given to inventions arising from routine development or production work carried out under contract to the AEC and of incidental value to nuclear energy. Into which classification any particular invention is placed is left to the judgment of the AEC, who also, in the case of "B" and "C" patents can decide whether ownership is to go to the contractor. If the decision is negative the contractor is entitled in the case of "B" patents to non-exclusive irrevocable royalty-free licence for use outside nuclear energy and in the case of "C" an irrevocable royalty-free licence with the sole right to grant sub-licences, again outside nuclear energy.

In comparison contractors with the U.K.AEA get a much better deal, and there is no question, where there are no formal contracts involved, of the AEA taking ownership of a patent solely because it supplied, for instance, an irradiation service. Under its contracts with industry there are two patent or invention classifications—"A" for "infield" work and "B" for outfield.

In the case of "A" inventions, the AEA take ownership, and if the contractor has taken out a patent on it, can acquire this. The contractor, if no national defence needs are involved, can be granted a sole royalty-free licence for "outfield" use with power to sub-licence, and a non-exclusive royalty-free licence for infield use in any part of the world, and with power to sub-licence by arrangement with the AEA.

If an invention is made with the Authority's assistance or collaboration the AEA reserve the right to join in the application for a patent. Joint patent ownership, however, is on the whole discouraged. A joint patentee cannot licence or assign his interest without the consent of the other patentee. As the Authority usually wants to be free to license whilst the contractors on the whole want to stop others using their patents, it is in the interest of the AEA not to indulge in joint ownership.

Industrial Reluctance in U.K.

It has been suggested that on the whole industry is reluctant to play too much a part with the AEA in the development of an invention unless there are prospects of making profitable use of it for "outfield" purposes. And if the "outfield" prospects are not very considerable, although there are profitable "infield" possibilities, a large concern might consider it well worth developing such an invention on its own rather than under contract with the AEA. In either circumstance industry would prefer to own the patents rather than licence them and it is on account of this preference that negotiations

are necessary for the classification of inventions as either "A" or "B."

On the whole inventions which are specifically nuclear are obvious and little difficulty is incurred over their classification. When they are less obvious however, it is not always easy deciding whether they are "A" or "B." If the parties concerned cannot come to an agreement the matter can be referred to an arbitrator either appointed by themselves or the Lord President of the Council. Similar difficulties are likely to be encountered over the classification of patents under the Euratom provision for notification of patent application. There appear to be no provisions for arbitration on this matter.

The French Solution

In France the problems arising from ownership of patents taken out under CEA research contracts have been largely resolved through the function of a special company, Société Française pour la Gestion des Brevets d'Application Nucléaire, which is charged with the commercialization of patents arising from the nuclear field both to the advantage of the CEA and industry. It is a joint stock company with membership from 54 French companies interested in nuclear activities, EDF and the CEA. Called Brevatome for short, it takes out and registers all patents arising from research contracts concluded with the CEA; and becomes responsible for exploiting them. It will also handle other nuclear patents passed on to it by members, although they are not obliged to do this.

In the field of nuclear energy Brevatome is obliged to grant, when necessary, non-exclusive licences on the patents it holds. The royalties obtained in this way are then shared between the CEA and contract inventor. A small deduction is made by Brevatome to cover expenses and a third of what is left goes to the inventor and two-thirds to CEA.

In the non-nuclear field, Brevatome members can obtain exclusive royalty-free licences and the right to sub-licence them. In the event of granting a sub-licence, however, the member is obliged to pay the CEA 30% of any royalties paid. Brevatome receive for their services a fee paid by the CEA. Exclusive licences in the non-nuclear field are granted, incidentally, only in expressly specified fields and are not general in their application.

Because of its specialized nature Brevatome has a greater chance of securing the utmost benefit from exploitation of a patent than a company working on its own. Further, licensing conditions are made more favourable for member companies than non-members.

The constitution of Brevatome is such to enable companies ceasing to have interest in nuclear activities to leave and new ones to join. A quarter of the capital however, is always held by the CEA, and 5% by EDF. The president of the company is a representative of industry, and the general manager, a former chief of CEA's commercial department. In addition to exploiting patents both at home and overseas, Brevatome collects and disseminates details of new patents from overseas and investigates legal and fiscal problems.

The Brevatome patents are either specifically or incidentally nuclear. If in the course of CEA contract work an invention which has no nuclear applications at all is discovered, the ownership goes to the contractor, subject to him granting the CEA a royalty-free licence. This has not always been the practice—at one time the CEA automatically took ownership as it did in the case of nuclear inventions.

RCN Makes a Change

Practice is also changing in this regard in the Netherlands, where industry in its contracts with the Reactor Centrum Nederland is tending to insist on ownership of patents arising from the contract. Whether the RCN will agree to this depends on the company's financial contribution to the contract and, usually, appropriate arrangements are settled from contract to contract. Where the company becomes the owner, RCN would be entitled to a licence, presumably free.

When RCN becomes the owner, the company is entitled to exclusive rights in its special field of activity outside nuclear energy. Royalties, calculated on the company's technical, scientific and financial contributions to the contract, are payable on these licences.

As the Reactor Centrum Nederland is jointly owned by the Government, electricity supply companies and private industry, special provisions are made for use of RCN-owned patents by the industrial members. These are entitled to non-exclusive, non-transferable licences for all technical fields, including nuclear energy, in all countries where a patent is held. In cases where the patent lies mainly within the special field of member companies these companies have the right to grant sub-licences.

Swedish Practice

In Sweden the practice is yet again different, although as in Holland, the central nuclear organization is part State, part private enterprise owned. The standard contract covering work to be carried out for Aktiebolaget Atomenergi, the Swedish Atomic Energy Company, provides for resulting patents to be owned by the contractor, designated in the contract as "designer." The Government and AE however have the right to use the invention royalty-free on nuclear plant owned and operated by them. The designer is entitled not only to exploit the invention, but also to grant sub-licences, provided, and the contract is insistent on this, "a reasonable licensee fee" is paid to the patentee. What is "reasonable" might be disputable, but it is obvious that the AE want to prevent exorbitant charges being made. If either the State or AE are part owners of a reactor on which work being carried out involves such a sub-licence, no fee will be charged on the State's or AE's share.

In Italy patent ownership and conditions of licensing where contracts with CNEN are concerned are agreed upon with each contract.

Switzerland also has no set formula for dealing with nuclear patents, but it is of interest to note that if research sponsored by the Swiss National Fund for the Promotion of Scientific Research lead to results that are patentable, the Fund must be informed. In the event of commercial exploitation of any patents taken out the Fund's original contributions must then be either partly or wholly refunded.

No such stipulation has been made as regards the Sw.Fr. 50 million contributed by the Government towards the SNA Lucens project. Instead the Government has reserved the right to use for its own purpose inventions and results of research and development arising directly from this project. Further it has equipped itself with the right to grant non-exclusive licences on such patents to other companies if considered in the public interest to do so.

Germany, likewise, has no special provisions. All patents are examined by the State patent office in Munich and, as in other countries, if any are considered to be of national importance, whether nuclear or not, are declared State patents. This provision was recently applied in the case of patents for the gas centrifuge.

Objections to Euratom

As a member of the Community, Germany does, of course, have to accept the Euratom patent provisions. There is, however, a decided opposition to the regulations requiring disclosure of patent applications before they are accepted. This is one of the provisions to which the U.K.AEA strongly object and according to informed opinion if Britain were to join there would in fact be almost a certainty of this provision being dropped.

The AEA are also known to object to the compulsory licensing provisions. Here, however, they are probably on less firm ground. Euratom have made it clear that every endeavour will be taken to ensure that the interests of patent owners will be safeguarded so far as is possible within the main objective of the Rome Treaty. To remove these particular provisions, however, would weaken their own safeguards against possible monopolistic control of an invention by anyone country or company, a possibility which could be against the interests of the Treaty objectives.

It was for similar reasons that the Authority itself built up its own strong position in the ownership of nuclear patents in the U.K. In view of this it would seem appropriate for the Authority to concede gracefully to the Euratom provisions, if, that is, it really wants the Community to be a success.

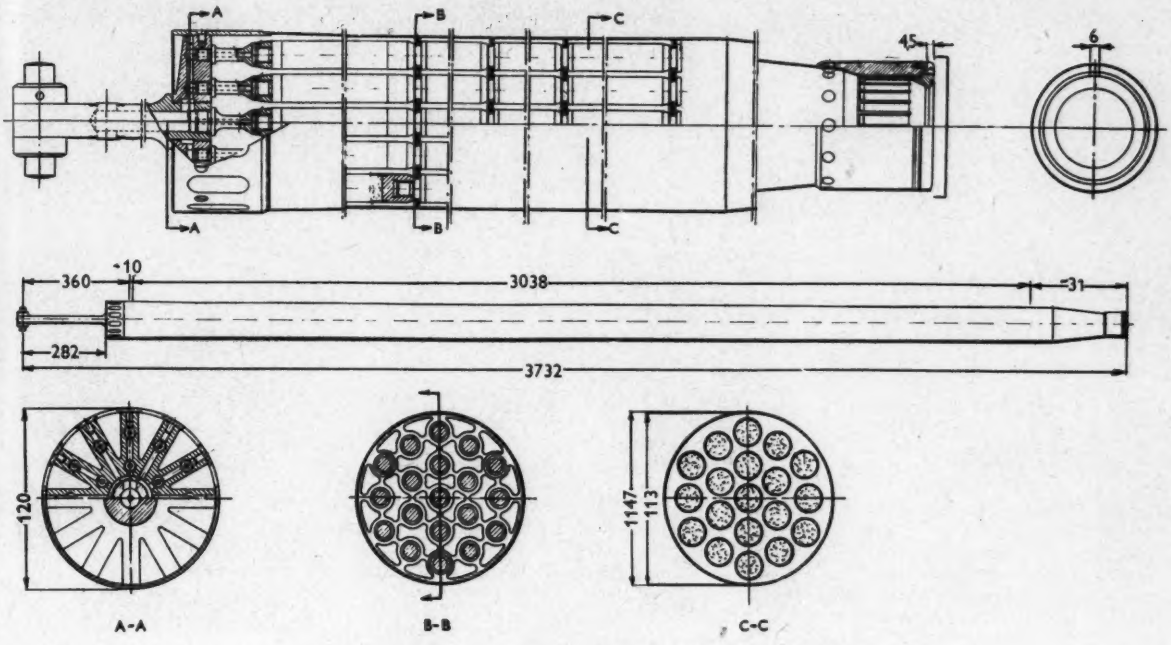


Fig. 1.—Cross-sections of the Ågesta fuel element (Mark 1).

Fuel Elements in Sweden, 1961

Although the Swedish power reactor programme is directed towards the development of a reactor system using heavy water as moderator and coolant and natural uranium as fuel, this approach does not exclude the use of slightly enriched uranium for occasional periods if strict economic considerations and other circumstances make this alternative fuel justified. The development programme aims at economic nuclear power in the first half of the '70s.

by HILDING J. MOGARD and BENGT T. NELSON*

THE first Swedish power reactor prototype is the Ågesta reactor (formerly R3/Adam)[1] which operates on natural uranium using fuel elements of 19 rod bundles containing sintered uranium oxide pellets canned in Zircaloy tubing. The reactor is intended for district heating (55 MW) and demonstration of power generation (10 MW) in its first operating stage. Criticality is scheduled for the end of 1962. The initial fuel core loading of 18 ton is at present being fabricated at AB Atomenergi in Stockholm. This particular fuel element design and its fabrication will be described in some detail below.

A scaled-up improved version of this first pressurized heavy water reactor type is the 100 MW(e) Marviken reactor (formerly R4/Eva) which is planned for full power operation in 1967. The fuel elements here incorporate some technological advancements on design and performance (Table 1). Decision on whether it will be built or not will be taken next year.

Within the scope of the reactor development programme studies have also been focused for some time on two other reactor types which technologically lie very well in line with the present approach, namely a pressurized heavy water reactor type with a "homogenized" fuel rod distribution of the core and a boiling heavy water reactor type with direct cycle steam generation, possibly with integral steam superheating. All these reactors under development or study will make use of the same type of fuel element rods as the Ågesta reactor, i.e. Zircaloy canned uranium oxide rods, except for superheating in the boiling reactor where another canning material like stainless steel is likely to be used. This common use of fuel element type is a great advantage for the concentration of efforts in the fuel development programme.

Fuel elements for the Swedish research reactors include relatively simple types of elements containing natural uranium metal or oxide canned in aluminium for the low power levels (as of the first Swedish 1 MW reactor R1 and zero power R0 reactor) as well as quite advanced types of elements containing highly enriched uranium for the high power level (30 MW) of the materials testing and research reactor R2. In past years fabrication of the former type of element has been undertaken from time to time and has thereby given valuable experience for the power fuel element development. Where possible, however, required amounts of uranium metal rods are bought directly from abroad so as to avoid divergence in efforts from the present oxide development line. The same fuel policy is also applied to the highly enriched fuel elements, for which there is at present no economic incentive for domestic fabrication.

The basic information regarding fuel element design and materials for the aforementioned power reactor fuel elements originated from abroad—in particular from the U.S.A. and Canada. Because of the lack of Swedish experience of in-pile fuel performance (the materials testing reactor R2 will not run at high power level until the beginning of next year) fuel design has had to be quite conservative for the first fuel loading of the Ågesta reactor (Table 1). A field of fuel development which, however, may be considered more genuine is the fuel fabrication, where some experience has been gained today that might be of wider interest. In parallel to the present Ågesta fuel element fabrication the second fuel core loading (1·6 ton of Zr-2 canned UO_2-elements) for the ENEA Halden project in Norway was recently manufactured at AB Atomenergi.

Fuel Design and Performance Data

Characteristic of current Swedish power fuel elements is the rod bundle design of which the Ågesta fuel element is repre-

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Fig. 2.—Ågesta fuel element assembly with and without shroud tube.

sentative (Fig. 1). The bundle is inserted in a Zircaloy shroud tube which under reactor service conditions stands vertically and serves to guide the water flow. To allow for axial rearrangement the element bundles can be separated into two or several sub-bundles which can be handled individually. For the first core loading of the Ågesta reactor—as for the second charge of the Halden reactor—shroud and fuel bundles are not separable to avoid complications.

The Ågesta fuel element (see Fig. 2) consists of a 3 metre long 19 rod bundle supported at the top. The individual fuel rod segments are all similar and quite conventional in design. The diameter of the UO_2 pellets measures 17·0 mm, the active segment length 728 mm and the Zircaloy can wall thickness 0·7 mm. The fuel segments are screwed together on top of each other to form a four segment rod. At each level of rod junctions there are flexible perforated spacer plates (Fig. 3) capable of allowing a certain amount of longitudinal movements of individual rods while keeping firmly the inter rod distance of 3·5 mm. Out-of-pile loop tests have shown the importance of a careful design of these spacer plates, fretting corrosion deserving special attention. The critical point of this fuel element design is likely to be a possible bowing of fuel rods onto one another under reactor service conditions. However,

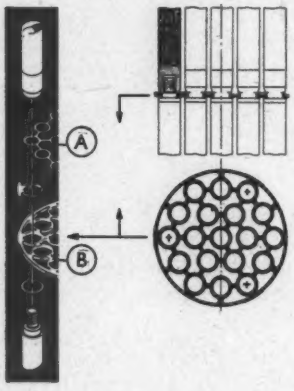


Fig. 3 (left). — Plate spacer arrangement for fuel rods (A). Flexible SS or Zr-2 spacer (B). Rigid Zr-2 spacer, 2×1 mm anchored at three fuel rod positions.

Fig. 4 (right). — Fuel element bundle showing top support for fuel rods and their transition parts (shroud tube disconnected).

a low dose irradiation test of a somewhat similar 7 rod bundle performed by the U.S. General Electric Co. for AB Atomenergi at VBWR has not indicated the rod bowing tendency to be severe. Development work on the Ågesta fuel elements has been going on for several years, but the lack of irradiation experience has been a serious drawback.

In Table I are summarized characteristic data for some types of power reactor fuel elements. As seen, the thermal loading of the Ågesta fuel is quite low in the Stage I operation.

TABLE I

Fuel Data For Swedish Power Reactor Fuel Elements (with comparative data for the ENEA Halden project)

	Ågesta Stage I	Marviken	Halden Core II
Fuel	UO_2	UO_2	UO_2
Enrichment, %	Nat.	Nat.	1·5
Pellet dia., nominal, mm	17·0	13·5	12·6
Active fuel segment length, mm	728	718	800
Active fuel assembly height, mm	3 047	4 417	1 700
Free space in segment, mm	10	6	8
Rod surface heat flux, max., W/cm²	37 (Stage II 63)	94	74
Heat loading, max., W/cm UO_2	216 (Stage II 370)	435	330
Segments per rod	4	6	2
Rods per element	19	27	7
Can	Zr-2	Zr-2	Zr-2
Can wall thickness, nom., mm	0·7	0·6	0·76
Canning tube, i.d., nom., mm	17·2	13·7	12·71
Shroud tube, o.d., nom., mm	115	130	73
Water outlet temp. °C	219	246	230 (steam)
Water inlet temp. °C	205	221	—

Power Fuel Fabrication

The UO_2 powder for the pellet production is produced at AB Atomenergi as ammonium uranate by a homogeneous precipitation out of a nitrate solution using carbamide[2]. The uranate product is calcined and reduced to UO_2 with hydrogen in a continuously operating rolling furnace at 800°C max. temperature. The powder thus obtained, being freeflowing and having a specific surface area of about 3 m²/g, is directly suited for pressing and sintering.

The UO_2 pellets are cold pressed at 4·5 ton/cm² using a zinc stearate binder and sintered batchwise at 1 650-1 725°C in molybdenum resistance furnaces in a hydrogen atmosphere. The average density obtained on the 20 ton pellet quantity now produced for the Ågesta reactor fuel elements runs about 10·5-10·6 g/cm³. Except for a substantial part of the pressing and sintering work, which is subcontracted to two private companies in Sweden, ASEA[3] and Kohlswa Jernverk, the fuel fabrication work is performed at the fabrication plant of AB Atomenergi.

Zircaloy material for the fuel elements is bought in the form of tubes, rods, and sheets and is carefully controlled for dimensions, properties, and possible occurrence of defects before approval for fuel fabrication work[4]. The most important part of this procedure is the ultrasonic control of cracks, flaws, and similar defects. Experience is that a varying number of canning tubes having serious defects of this kind may occur in many consignments from several tube manufacturers.

The canning operations are performed along the same principal lines as those being used by manufacturers in U.S.A.[5] and Canada[6]. The first end plug welding is carried out in a small box under streaming argon gas using tungsten electrodes whereas the second end plug welding is done in an argon-filled glove box chamber, where also helium at intervals may be introduced into the fuel rods through a boring in the second

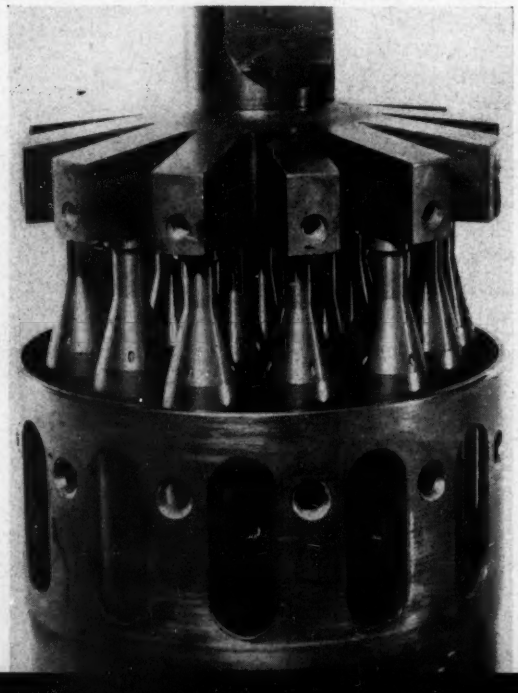


Fig. 5.—Plant for pressing and sintering uranium dioxide pellets.

end plug. The latter end plug holes are sealed by arc welding.

All welds are X-rayed and the enclosed fuel rods are all helium leak tested. An electron beam welding machine is to be placed in operation this autumn and it is hoped that this particular production technique will permit a statistical instead of a 100% control procedure, at least so far as the X-raying is concerned.

The fuel element rods and the assembly components are surface conditioned and autoclaved for 72 h in steam at 400°C and 45 atm. Chemical pickling in conventional HNO_3-HF acid[7] and/or electropolishing is used for the surface conditioning. The electropolishing method has the advantage of giving a smoother surface, better dimensional tolerances and a more defect-free oxide film after autoclaving but is more costly than the chemical polishing.

Present fuel fabrication capacity amounts to about 2 ton a month on one-shift work. The delivery of the first fuel charge for the Ågesta reactor will be completed by mid-1962. The expected fuel cost will run about 425 Sw.Crowns/kg UO_2 (82 $/kg UO_2) including the natural uranium material.

The fuel elements for the second core of the ENEA Halden Boiling Water Reactor in Norway were designed in co-operation with the Halden project staff[8] and produced by AB Atomenergi along the same principal production scheme as the Ågesta fuel elements. The 1·5% enrichment of these oxide elements required extra precautions due to the criticality risks.

Fuel Development

More effective use of chosen materials for the fuel element components, improved design and reduced fabrication costs are the main aims of the Swedish fuel development programme. In general, fundamental and applied studies must thus go together to determine the limiting factors of materials and components and the different steps in the fabrication process have to be analysed for possible economic savings. These problems can only be approached on certain points in a small country like Sweden. Substantial means and efforts have already been laid down on a forthcoming increased development programme. A good starting point is being obtained by the current work on the first Ågesta fuel charge. A sizeable metallurgical hot cell laboratory has just been put into operation at the research centre at Studsvik, where irradiation tests are to be performed in the R2 reactor. A pressurized hot water loop and a hydraulic rabbit facility are available when the reactor starts regular work on high power level at the beginning of 1962. Until now a few irradiation tests have been made abroad and later examined at Studsvik. For some time the physical and chemical processes and properties connected with the use of UO_2 and Zircaloy 2 have been studied in the non-radioactive state; in particular should be mentioned the effect of impurities on the stoichiometry of the oxide at high temperature service conditions, the isothermal transformation of beta phase in Zircaloy 2[9], structure transformation during the manufacture of Zircaloy 2[10], and the solubility and occurrence of hydrogen in the structure of Zircaloy and its influence on the mechanical properties of this material[11].

Possible advancements on the design of fuel elements are partly connected with thinner cladding (0·6 mm), longer fuel rod segments (1 500 mm) and special spacers, reduced end plug materials, and tighter oxide pellet to can clearance. On the fabrication side two items are of particular importance because of their large total contribution (about 45%) to the fuel fabrication cost; the charges for (a) Zircaloy can material and (b) the pressing, sintering and grinding operations. As in many other laboratories the vibratory compaction method is being examined.

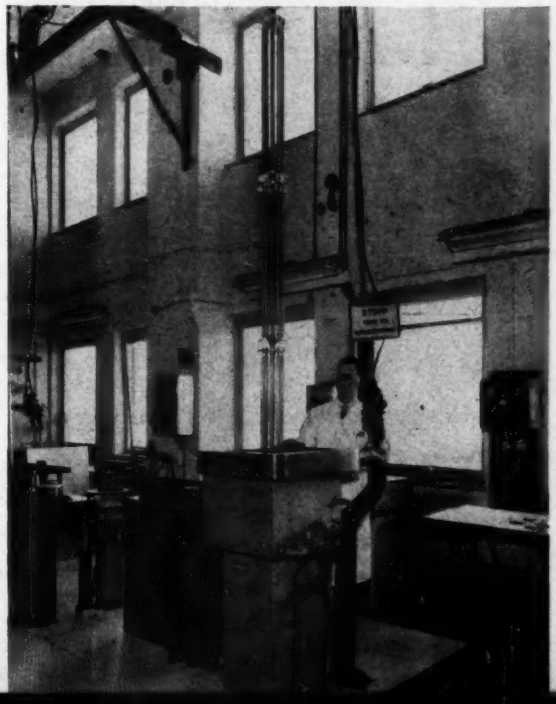
Acknowledgment

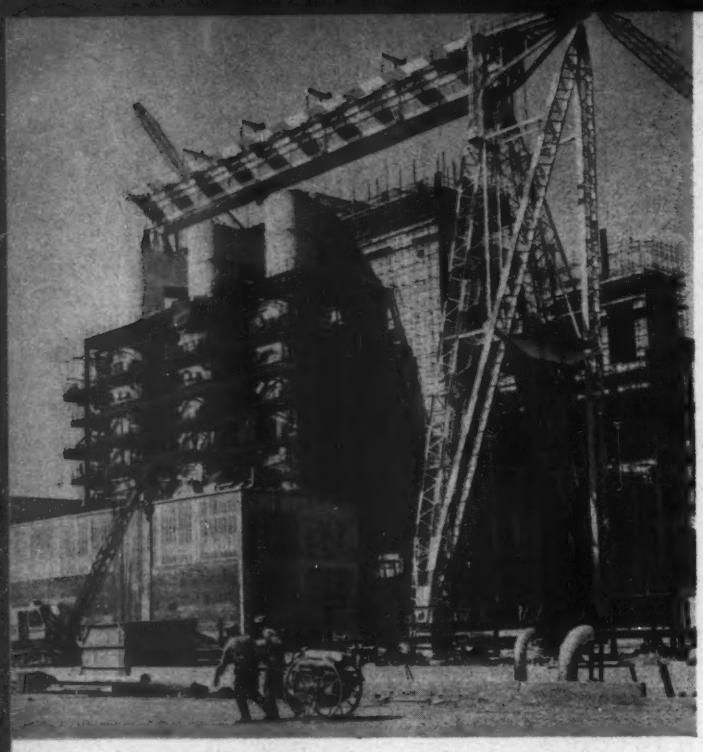
The authors are indebted to their colleagues at AB Atomenergi and participating organizations for their direct or indirect contributions to the work described here.

REFERENCES

1. Margen, P. H. *et al.* R3—A Natural Uranium, Heavy Water Reactor for Combined Electricity Production and District Heating. Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva 1958, P/135, Vol. 8, pp. 220-237.
2. Gelin, R., Mogard, H., and Nelson, B. Refining of Uranium Concentrate and Production of Uranium Oxide and Metal. Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva 1958, P/179,Vol. 4, pp. 36-39.
3. Halle, L. Production Sintering of UO_2. EAES Symposium on Reactor Materials, Stockholm 1959, Paper S:9. (Internal report).
4. Nelson, B., Nyström, U. *et al.* Production Control of Zircaloy Fuel Cladding. Proceedings of the IAEA Symposium on Fuel Element Fabrication with Special Emphasis on Cladding Materials, 1960, Vol. 2, pp. 29-44.
5. Spalaris, C. N. Fuel Elements for Dresden (U.S.A.). *Nuclear Engineering*, June 1959, pp. 253-258.
6. Mooradian, A. J., and Robertson, J. A. L. Candu Fuelling Costs—Breaking the 1-Mill/kWh Barrier. *Nucleonics*, Oct. 1960, pp. 60-65, 122.
7. Hydén, L. Production Pickling of Zircaloy Cladding. Proceedings of the IAEA Symposium on Fuel Element Fabrication with Special Emphasis on Cladding Materials, 1960, Vol. 1, pp. 247-249.
8. Mogard, H. Second Fuel Charge of the Halden Boiling Water Reactor. Advanced Course on Fuel Elements for Water Cooled Power Reactors, Kjeller, Norway, Sept. 1960, Vol. II, Section III, pp. 3-20.
9. Ostberg, G. Metallographic Study of Isothermal Transformation of Beta Phase in Zircaloy-2. Proceedings of the IAEA Symposium on Fuel Element Fabrication with Special Emphasis on Cladding Materials, Vol. I, pp. 79-109, also in Jernkontorets Annaler 145 (1961) pp. 119-142 (in English).
10. Ostberg, G., Attermo, R. Structure Transformation in Zircaloy-2 during Some Hot Working Processes. *J. Nuclear Materials*, in print.
11. Ostberg, G. Determination of Hydride Solubility in Alpha Phase Zirconium, Zircaloy-2 and Zircaloy-4. *J. Nuclear Materials*, in print.

Fig. 6.—Production line for degreasing and pickling of Zircaloy fuel rods.





Latina's goliath straddles the near-complete reactor building.

The first gas circulator to be completed has already undergone the full test programme.

Latina

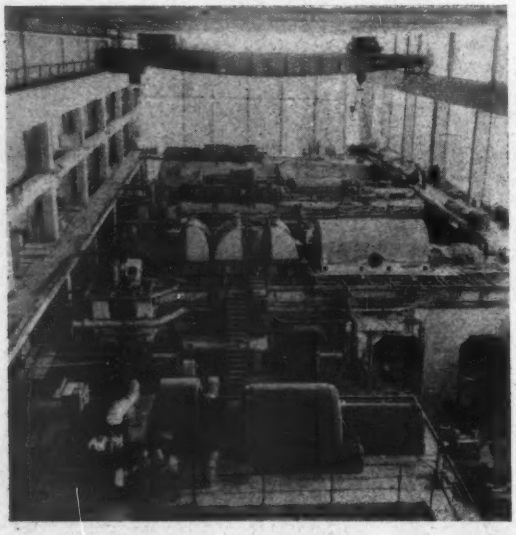
THE 200 MW nuclear power station at Latina, some 40 miles south of Rome, is now entering the final stages of construction. Although the station is some months behind schedule it is expected to go critical next year. Latina is being built by The Nuclear Power Group Ltd. in association with Agip Nucleare, and Italian industry is responsible for a high proportion of the construction.

The photographs on this page—most of which were taken at the end of September this year—give some idea of the present state of progress. On the reactor building the roofing and curtain walling is being installed and the interior surfaces are being finished. The cooling pond nears completion.

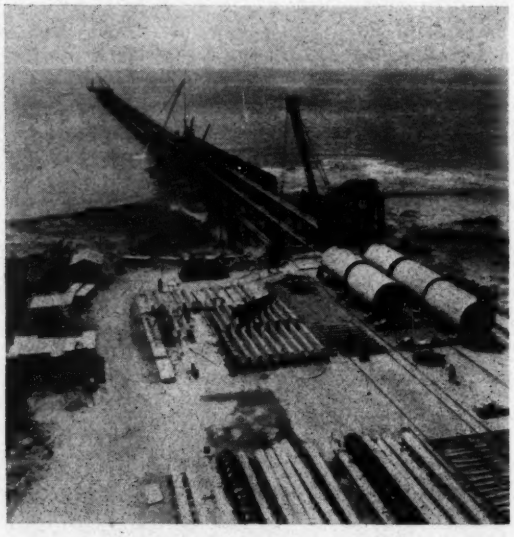
So far as mechanical work is concerned the CO_2 circulators are in course of installation and the first has been successfully tested; the interior of the reactor pressure vessel has been cleaned and made ready for the installation of the graphite. Work on the main gas ducts, the reactor standpipes and the steam pipelines to the turbine hall continues.

In the turbine building the first turbo-generator is complete; the second is well advanced (see photo below) and the foundations are ready for the third. The small station supply set has already steamed, the supply being taken from the auxiliary oil-fired boiler on the site.

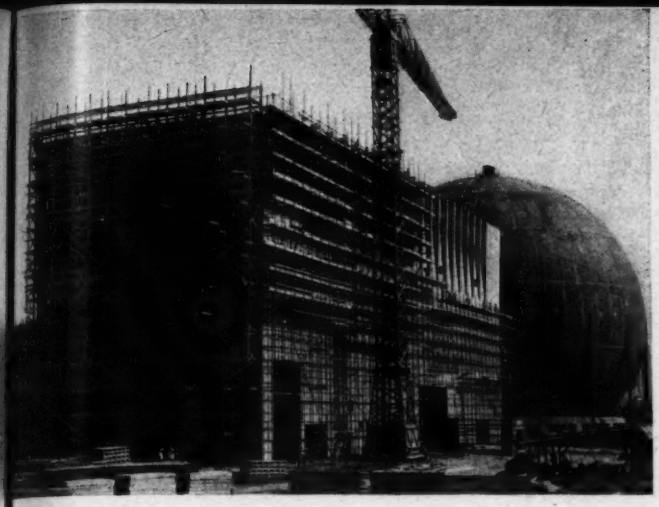
In the reactor control room most of the instrumentation is in position and the main work centres on wiring up individual panels. Finally, the cooling water inlet pipes are being positioned at the sea-end of the intake culvert.



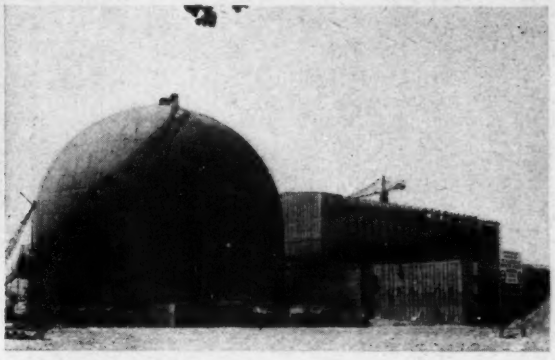
Interior of the main turbine hall. The auxiliary turbine in the foreground has been tested.



Cooling water for Latina is piped from the sea.



SENN is responsible for the construction of the turbine hall, the roof being of concrete cast *in situ*.



(Below) Chicago Bridge completed the reactor containment shell in record time.

Garigliano

ON the Garigliano site 70 miles south of Rome, International General Electric Operations S.A., the company responsible for the erection of a 150 MW(e) BWR, report excellent progress. The spirit of friendly rivalry and co-operation between IGEOSA and SENN has spurred their respective construction teams to work ahead of schedule. This is a notable achievement when it is recalled that the site was subject to serious flooding last winter.

At the present time the turbine hall is almost complete and work has started on the installation of such equipment as dump condensers and so on. The reactor containment vessel which was due for completion on July 1 was, in fact, handed over by Chicago Bridge some eight weeks prior to that date. If the present rate of progress is maintained (and it may well be improved) there is every possibility that Garigliano will emulate its predecessor Dresden and go critical well ahead of schedule.

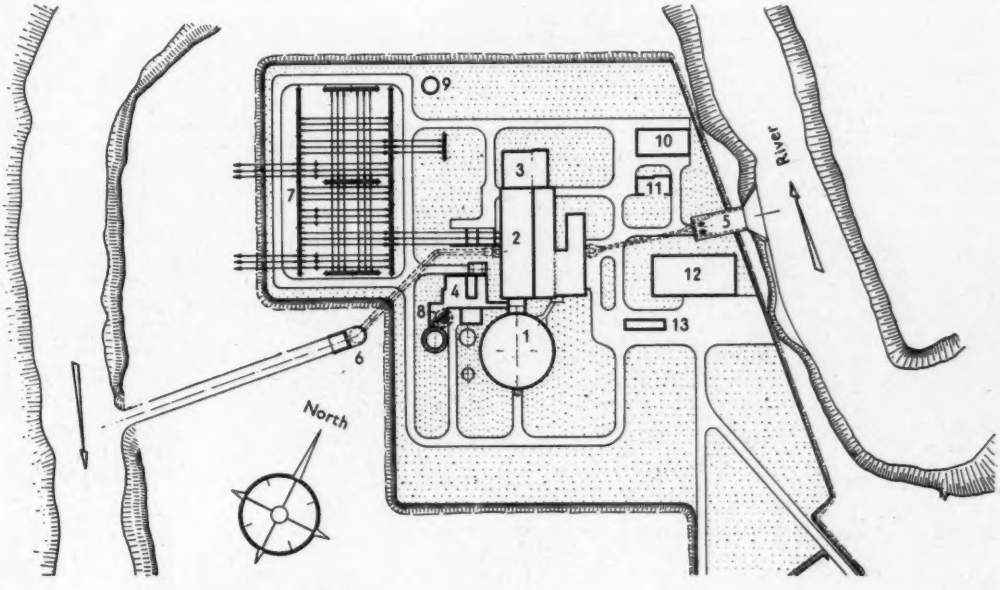
The reactor pressure vessel is notable because, for the first time, forged construction was adopted in preference to all-welded plate. The contractor was an Italian company, Terni. A large proportion (about 70%) of the remainder of the station will also be supplied by Italian companies. The single-shaft 160 MW turbine, comprising an H.P., M.P. and L.P. stage with double outlet flow, is being manufactured by Ansaldo.

PRINCIPAL CONTRACTOR

INTERNATIONAL GENERAL ELECTRIC OPERATIONS S.A.
Consultants: Ebasco Services Inc.

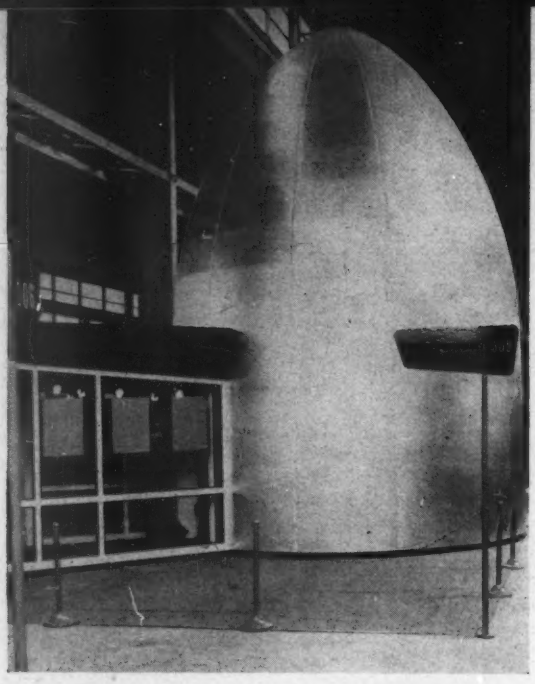
MAIN SUPPLIERS

ANSALDO (Italy)	Turboalternator and condenser
ANSALDO S. GIORGIO (Italy)	Main transformers and electric motors
BONALDI (Italy)	Heat exchangers
BATIGNOLLES (France)	Emergency feed pump
C.G.S. (Italy)	Metering transformers
DALMINE (Italy)	Carbon steel tubing
DIKKERS (Netherlands)	Main valve
F.B.M. (Italy)	Feed water preheaters
GAVAZZI (Italy)	Control boards
G.E. Co. (U.S.A.)	Nuclear fuel and instrumentation. Reactor circulation pumps.
HANREZ (Belgium)	Throttle valves
K.S.B. (Germany)	Various pumps
INFILCO (U.S.A.)	Deionizers
ITALSTRADE (Italy)	Civil engineering works
MAGRINI (Italy)	Busbars in conduits
MANNESMANN (Germany)	Stainless steel tubing
S.A.E., Napoli (Italy)	HV line pylons
STORK (Holland)	Secondary steam boilers
THERMOMECCANICA (Italy)	Deionizers
TERNI (Italy)	Steel plate for shell. Reactor pressure vessel Emergency condenser
TECNOMASIO ITALIANO B.B. (Italy)	220 kV air breakers
TOSI-ATB (Italy)	Cylindrical body
ZERBINATI MERIDIONALE	Metal furniture



Garigliano site plan.

1. Reactor building
2. Turbine hall
3. Mechanical workshop
4. Radioactive waste treatment
5. Cooling water intake
6. Cooling water outlet
7. Electricity distribution
8. Chimney
9. Water tank
10. Store
11. Chlorinator building
12. Administration and canteen
13. Gatehouse



As part of the programme of publicizing nuclear matters in Germany the Deutches Atomforum exhibited this reactor model at the German Industries Fair at Hannover this year.

Germany

AT the beginning of 1961 there was reasonable optimism in the German reactor research centres and within the nuclear engineering industry that the year would see concrete decisions taken regarding Germany's reactor programme and the future course of development plotted in a definitive manner. In particular it was anticipated that the position regarding large nuclear power stations and a ship reactor would be clarified. At the same time the budget for 1961 rather indicated that little of importance could materialize and sceptics re-echoed the discouragement of the reactor constructors clearly expressed at the meeting of the German Atomforum, October 11-13, 1960, in Karlsrühe. This mood prevailed in spite of the confident words of Germany's Minister for Atomic Energy, Professor Balke, who at the time was expecting that the next phase in the construction of nuclear power stations would be initiated by the nuclear industry. The industry itself, conscious of the overproduction of coal, ready availability of oil and present full employment was hesitant to make the necessary investment of many million DM in a yet-to-be-proved technology.

In the end, the Ministry of Atomic Energy came to the opinion that State support of reactor development and construction could no longer be avoided. As a result, four companies (AEG, Babcock and Wilcox, BBC-Krupp and Interatom) received financial support to the extent of DM 16-18 million for the performance of reactor studies, and Siemens received a grant of DM 100 million for the construction of the multipurpose reactor at Karlsrühe.

Influence of Atomforum

A major influence on this revision of policy has been the German Atomforum who, with the German Atomic Energy Commission, have been actively pushing the Government towards a new approach. The Atomforum has also demanded that the previous year's budgetary allowance of DM 21·15 million for the construction of research and experimental reactors should in future be transferred from the extraordinary budget into the ordinary one, if not for 1961, at least for 1962. In other matters also the Atomforum is gaining in authority and its reputation was enhanced by its appearance as a body at the Hannover and Achema fairs.

It is also largely as the result of the Atomforum's work that the Bundestag on June 29 recommended that the Government should increase its support to the nuclear reactor programme. Thereupon the Bundesminister for Atomic Energy put up a figure of DM 500 million as the atomic energy budget for 1962—as against DM 190 million for 1961. The final figure agreed by the Government will show to what extent the Government has recognized the urgency of a suitable development programme for Germany's nuclear industry.

Expenditure by the Bundesministry of Atomic Energy and the Bundesläender in Germany over the past six years including administration costs are shown below, where the figures relate to million DM. These figures are not impressive when compared with the expenditure in other major European countries, but if the plans of the BMAE for a DM 500 million budget should come to fruition it would mean that the overall expenditure in 1962 was double that for 1961.

It is perhaps not surprising in view of the limited investment in development that no real projects for large power stations

German investment in million DM.

1956	1957	1958	1959	1960	1961
44.4	126.7	241.3	270.2	298.0	331.1

exist in Germany and it still seems questionable if current projects will get through to the construction phase. The Kernkraftwerk Planungsgesellschaft (former AKS) group have yet to decide whether to apply for Euratom collaboration whilst at the same time the Bewag reactor project, even though it has completed a satisfactory study stage, is still fluid because of political problems, in spite of the fact that the value of this reactor would be very great should a second blockade materialize.

Siemens MZFR

There has however been one important decision in the field of power reactors during the past 12 months; the Siemens general-purpose reactor (MZFR) will be built with Government support of DM 100 million at Karlsrühe under the direction of the former RWE director Dipl. Ing. Heinrich Schöller. The MZFR developed by Professor Finkelnburg's group and designed for a thermal power of 200 MW and a 50 MW electrical output is a heavy water moderated and cooled pressure tube reactor. Fuel would be 13·5 t of UO_2 in 230 fuel elements of, say, 70 kg each, the individual elements consisting of 37 Zircaloy tubes containing the UO_2 pellets. The complete core will occupy a cylinder 3·14 m diameter and 3·69 m high. Maximum burn-up is anticipated to be about 4 000 MWd/t. In the pressure tubes the heavy water coolant

TABLE 1: POWER REACTOR PROJECTS.

TYPE	POWER	CONTRACTORS	OWNERS
		Power Studies	
PWR ..	150 MW ..	Siemens	Atomkraft Bayern
BWR ..	100 MW ..	AEG	SKW–Hannover
Calder ..	100 MW ..	Babcock and Wilcox	SKW–Hannover
OMR ..	150 MW ..	Interatom	Baden–Wurtt
OMR ..	15 MW ..	Interatom	Baden–Wurtt
BWR ..	250 MW ..	AEG	RWE
Gas cooled..	300 MW ..	Siemens	RWE
PWR ..	15 MW ..	BBC–Krupp ..	Bundesministry
BWR ..	25–30 MW ..	AEG	Atomic Energy
Gas cooled ..	15 MW ..	Babcock and Wilcox	Atomic Energy
Sodiumcooled	10 MW ..	Interatom	Atomic Energy
		Ship Studies	
OMR ..	10 000 s.h.p...	Interatom	GKSS
BWR ..	20 000 s.h.p...	AEG	Deutsche Werft Hamburg
PWR ..	10–30 000 s.h.p.	Siemens	Howaldtwerke, Hamburg
AGR ..	20 000 s.h.p...	Babcock and Wilcox	Blohm and Voss, Hamburg
HT–gas cooled	10 000 s.h.p...	BBC–Krupp ..	AG Weser, Bremen

TABLE 2: RESEARCH TEST and EXPTL. REACTORS

PLACE	TYPE	PURPOSE	POWER	DATE OF CRITICALITY
Operating Reactors				
Munich	Swimming pool	Research reactor	1 MW	31.10.57
Frankfurt	Homogeneous	Research reactor	50 kW	10. 1.58
Berlin	Homogeneous	Research reactor	50 kW	24. 7.58
Geesthacht	Swimming pool	Research reactor	5 MW	23.10.58
Garching	Argonaut	Siemens test-reactor	10 kW	23. 6.59
Kahl	PWR	Power reactor	15(30)MW(e)	13.11.60
Grosswelzheim	Argonaut	AEG-test-reactor	1 kW	27. 1.61
Karlsrühe	Heavy water	Research reactor	12 MW	7. 3.61
Jülich	Swimming pool	Research reactor	5 MW	probably Oct. '61
Reactors Under Construction				
Jülich	Dido-type	Materials testing	10 MW	end of 1961
Karlsrühe	Argonaut	Teaching reactor, Siemens	10 MW	end of 1961
Mainz	Pulse-reactor	Triga-Mark II	30 kW	—
Garching	Homogeneous	Teaching reactor	0.1 W	—
Jülich	Pebble-bed	BBC-Krupp reactor	15 MW(e)	1964
Karlsrühe	Heavy water	Multi-purpose MZFR Siemens	50 MW(e)	—

will be at a pressure of 100 kg/cm² (1 420 psi) and a mean temperature of 250 to 280°C. The temperature of the moderator will be adjustable over the range 120 to 220°C with a mean of 153°C and this parameter will be used to control the reactivity of the assembly. Additionally there will be one control rod for fine adjustment and 16 safety rods giving a total negative reactivity of 8·5%. Steam will be generated by an external heat exchanger at 240°C and 33 kg/cm² (470 psi) pressure at a maximum rate of 280 t/h. Future research will include fuel element testing, loop experiments, research on the thorium-U^{233} fuel cycle, plutonium production, etc.

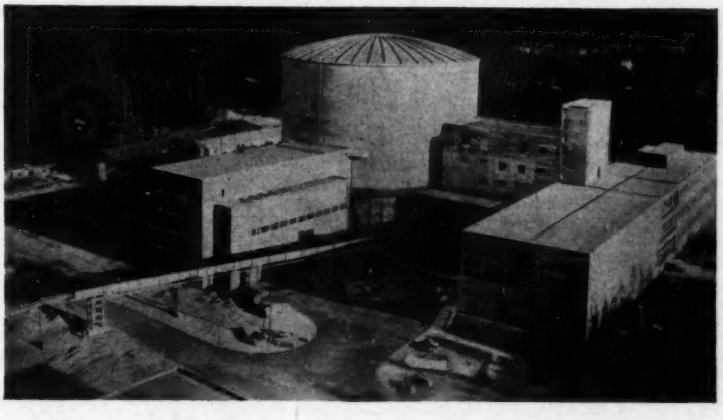
Kahl

At Germany's first nuclear power station, Kahl, a licence permitting full power operation is still awaited. The reactor first went critical on November 13 last year and the delays in coming up to full power are indicative of the cumbersome nature of the licensing procedure in Germany. Following start-up, the large priming source was delivered in December last year and in the light of the Dresden stress corrosion cracking the control rods were reconditioned. This work however was finished in March of this year but the operating licence did not materialize until June, following which current was first delivered into the RWE grid network on June 17. Since then the reactor has been operating at an electrical power of about 11 MW.

It is, similarly, licensing difficulties which have led to a serious delay at the construction site of the other small power reactor, the Schulten reactor at Jülich, where work has been interrupted for several months because a building licence has not been forthcoming. There was certain opposition to the project including some from the local population but AVR now hopes that the project may get under way in 1964.

Research Establishments

The research reactors and their research programmes have fared somewhat better; for example, a number of research reports have been published following work on the swimming pool reactor at Munich; at the reactor station of GKSS, at Geesthacht, experimental work is in full swing. At the research centre of Karlsrühe, FR 2, the first reactor of German construction went critical on March 7 of this year since which time it has operated at zero power to test critical assemblies and the reactor ancillaries. It is expected that early in 1962 the new aluminium and stainless steel tanks will be finished (which have been necessary because of certain faults developing in the original tanks) and following their installation full power operation can begin.



FR 2, the first reactor of German construction, went critical on March 7.

Finally, at the Kernforschungsanlage, Jülich, the remaining German reactor research centre, an inauguration ceremony took place on September 28 this year. The ceremony was held within the building housing the Merlin reactor which is completing its criticality tests at the present time. Among the guests at the inauguration were Lord Hailsham from the U.K., M. Hirsch, president of Euratom, and the vice-president M. Medi, the Bundesminister, Prof. Hahn, and etc. At present Jülich covers an area of 1·8 km² but this might be enlarged up to about 4·5 km² if necessary. DM 150 million have been invested so far, including 32·5 million and 13 million respectively for the Dido and Merlin type reactors. By 1964 when the first constructional period will have been completed, investments will have totalled about DM 200 million of which 52 million will have been paid by the Bundesministry of Atomic Energy.

Ship Propulsion

Completely separate from the preceding projects is the ship reactor project. In principle, each reactor type is to be checked for its suitability as a ship reactor at the request of the Bundesministry of Atomic Energy. As the OMR project of GKSS and Euratom is the most advanced and because of the support of Euratom to this project it is most probable that Germany's first nuclear powered ship will be propelled by an OMR. GKSS at first intended to use an old tanker, the Esso-Bolivar, for the installation of the reactor but a more careful analysis showed the costs of alteration of the old ship to be nearly as high as those for the construction of a new one. Furthermore the desire of BMAE to test a variety of reactor kinds can be better accommodated with a new ship.

In the event, GKSS called for proposals from interested German shipyards and seven complied. The Board finally decided that a bulk carrier should be Germany's first nuclear powered ship and at its meeting on October 5 the Board selected the offer of the Howaldtswerke at Kiel so that construction can begin in the near future. It remains to be seen how long it will be before actual building begins.

PROGRESS IN NORWAY

1. The Halden Project

THE Halden project has always been of considerable interest, as being the only boiling heavy water reactor in the world; its containment, in a cavern excavated underneath a mountain, is another unusual feature. Owned by the Institutt for Atomenergi, its operation was undertaken as an OEEC project by an agreement signed in 1958 and later extended to the end of 1962.

Previous references have several times been made in *Nuclear Engineering*, a fairly complete description of the reactor (then under construction) appearing in March, 1959 (p. 106), and a general review of the future programme, by Henrik Ager-Hanssen, in charge of research, appeared in the issue of July, 1960, p. 293. The present review is compiled from the OEEC annual reports and the quarterly reports of the Halden project itself.

Criticality was first achieved in June, 1959, and was followed by some six months of low-power experiments. The reactor was then shut down in January, 1960, for inspection and minor modifications. Some slight corrosion of the fuel elements had occurred; repairs were effected and, at the same time, the heavy water purification system was modified. Improvements were also made to the leak-tightness of the reactor hall.

The reactor was started up again in August, 1960, and boiling was achieved for the first time on October 5, at a power of 3 MW, and a second series of experiments was undertaken, scheduled to end in May, 1961.

Table 1

Comparison of HB-WR operating parameters, with first and second fuel charges.

	First charge	Second charge
Total power (MW)	5	20
Power to steam (MW)	4	18
Subcooled power (MW)	1	2
Mass flow (kg/h)	7 500	43 000
Operating pressure (atm)	5	30
Outlet temp. (°C)	150	230
Secondary steam pressure (atm)	2·9	10
Secondary steam temp. (°C)	132	180
Feed temperature (°C)	124	170
Secondary steam flow (kg/h)	6 650	37 200
Fuel elements	296+7 spikes	100
Fuel	Nat. U / UO_2	UO_2
Enrichment (%)	— / 1·5	1·5
Inventory (kg)	7 000 / 136	1,953
Max. centre temp. (°C)	285 / 660	2 760
Canning	Al 25 / SS 18/8	Zirc.–2
Max. surface temp. (°C)	150 / 170	260
Surface heat flux (W/cm²)	23 / 20	121
Core		
Mean power density (W/cm³)	0·33	1·85
Peak initial flux (n/cm²s)	$1·2\times10^{13}$	$5·4\times10^{13}$
Equivalent diameter (cm)	284	240
Equivalent length (cm)	240	240
Voidage in shroud (%)	12·5	—
Lattice type	Triangular	Open hex.
Lattice pitch (mm)	130	130
Number of lattice points	325	325
Number of control rods	10	30
Material	Cd–Ag	Cd–Ag
Control mechanism	Solenoid	Magnetic Jack

Experimental Programme

As may be imagined, the quantity of data produced will require some considerable time for full analysis and interpretation.

Static (steady-power) experiments were carried out at a nuclear power of about 1 kW, the system being externally heated using the electrical heating of the secondary circuit. Temperature coefficient, material buckling and regulating rod calibration experiments were carried out at up to 150°C. The average value for the temperature coefficient was found to be approximately 20 pcm/°C (1 pcm = 0·001% $\Delta k/k$). Void coefficient was determined to average 95 pcm/MW. Xenon poisoning was also evaluated.

Dynamic experiments were carried out using a rotating cadmium shutter equipment, the design being based on mock-up experiments carried out in Jeep, giving a peak-to-peak reactivity oscillation of amplitude varying from approximately 0·02% to 0·1%. Measurements were made over a power range of 1·3 MW to 3·7 MW with oscillations varying from 0·002 to 10 c/s at each power, enabling determination of reactivity/power transfer function.

Steam load experiments have also been carried out to determine reactor response to step perturbations and periodic pulsing of the secondary steam load. A considerable amount of work has also been carried out on the high noise levels indicated in the records of both primary and secondary steam flow, as well as in the nuclear power signals.

Instrumentation

In direct support of the experimental dynamics programme, a considerable amount of work has been done on in-core instrumentation for the second core. At present, many quantities, e.g., channel coolant temperatures, steam voids, cladding temperatures, coolant velocities, etc., can only be calculated or inferred from what might be termed the "bulk" measurements such as power, pressure and steam flow. Development of successful in-core instrumentation will not only greatly assist the study of boiling dynamics in the Halden reactor, the instruments will be of value to other reactor projects.

The actual types of instrument under development include low-pressure-drop turbine flow meters (using a 4-bladed magnetic rotor and stationary pick-up coils); capacitative measurement of steam voids; capacitative measurements of fuel length changes and a hot-wire anemometer to combine temperature and velocity measurement. It is planned to construct four special fuel elements for the second charge, each incorporating this instrumentation.

An irradiation programme has been carried out on components to determine their suitability for in-core instrumentation.

Operation

In general, the operation of the reactor seems to have been very satisfactory although, of course, it must be remembered that with the first fuel charge it is not working at more than a fraction of full power. (A comparison of working parameters of the first and second loadings is given in Table 1.) Nevertheless, with steam load changes of up to 30%, the reactor power followed the change in demand smoothly without overshoot or oscillation.

During the period January/March, 1961, there were four scrams, and five "fast-ins" from power levels above 1 kW. One scram occurred when the rectifier switch for the control-rod motors was inadvertently turned off, and two were initiated by the shut-down amplifiers when the scales were not changed promptly whilst the reactor was being brought up to power. The fourth scram and two of the fast-ins occurred during the transfer function measurements; the power oscillations gave apparent doubling times below the trip settings. The period safety trips were by-passed during the remainder of the oscillation experiments, after due precautions had been taken to see that the independent power level trips were in order. Of the remaining fast-ins, two were caused by damage to secondary steam circuit monitors due to the bleed stream not being sufficiently cooled; the remaining one was caused by a drop in pressure of the Halden water main below the trip point setting and the failure of the 3-way valve to operate to the stand-by supply. This last was unimportant for first-charge conditions, but special consideration is being given to adequacy of cooling water supply in the second charge safeguards report.

The extremely low loss of heavy water has been an interesting feature. During the quarter's operation, the total loss has been estimated at 0·5-litre—too small to be inside the accuracy of the inventory techniques—although several small leaks have been found and corrected. These included the glands of two stainless-steel needle valves in the deuterium-in-steam analyser circuit. These have been replaced by bellows-sealed valves. Some trouble has also been experienced with flanges and drain plugs sealed with Teflon gaskets, which have been replaced with Permanete rubber-filled asbestos gaskets.

Engineering

Reference to Table 1 will show that the performance of the reactor will be very different with the second core, and a considerable amount of engineering effort has been expended on the design and procurement of the additional plant which will be required as well as the actual core.

The existing "steam transformer," i.e., the heavy/light steam heat exchanger will be inadequate to deal with second-core heat output and a new steam transformer is to be installed in parallel.

On the secondary side another important modification is scheduled. Previously, the

secondary steam has been discharged to atmosphere and, in spite of phosphate treatment and blow-down, chloride concentration has been undesirably high. This will be minimized by running the secondary steam in a closed circuit through a new steam generator and discharging the tertiary steam to atmosphere.

In addition to the second steam transformer and the secondary/tertiary steam generator, new feed pumps are being supplied.

On the primary side, an additional subcooler is scheduled and the D_2O purification system is being completely replaced by a new system having a capacity of 3 200 litre/h.

The new primary steam transformer is being provided with a double tube plate, having a space of about 1 in between the two. Tubes will be rolled into the inner plate at two places and, after individual helium leakage tests, the outer plate will be installed and the tubes rolled and seal-welded into position. The two plates are afterwards welded together. As the space will be at atmospheric pressure any leakage will "flash," and chloride may be deposited. At present, arrangements are being made for periodic flushing with de-ionized water which will subsequently be tested for chloride concentration; at a later date it may be decided to arrange for a continuous circulation of de-ionized water.

The new secondary/tertiary steam generator is of the vertical straight-tube type, with a total heat transfer area of 240 m^2 (2 582 ft^2). The normal working conditions for the secondary side will be 17·4 atm and 205°C, with peaks at 38·7 atm and 250°C. For the tertiary side, the corresponding figures will be 10 atm and 180°C with peaks at 25·5 atm and 225°C.

Control Gear

The increased reactivity of the new core requires a much greater amount of control, and 30 cadmium-silver rods will replace the 10 of the original scheme. The resultant closer pitch of the control rods precludes the use of the original mechanisms which, as briefly mentioned in the original description (*Nuclear Engineering*, March, 1959, p. 108) are moved within a pressure-tight enclosure by external magnetic coils which themselves are raised and lowered by motor drive. It was decided to replace them by mechanisms of the magnetic-jack type, and these have been under development at Kjeller. A prototype has been subjected to 1 000 cycles of withdrawal and scram at working temperature and pressure (230°C, 40 atm).

Other Work

In addition to the above, further modifications have been made to the fuel handling gear, and a new facility is being constructed for spent fuel handling and storage.

Future plans have been announced (*Nuclear Engineering*, October, 1961, p. 403) to convert the reactor for spectral-shift operation (i.e., the use of a D_2O/H_2O mixture as moderator, the relative proportions being changed to compensate for change of reactivity during life) when the present programme is completed, i.e., by 1963, say. This would require a new core and, to obtain a greater stability margin for the system, a new sub-cooler loop capable of removing up to 50% of the total power.

2. Research at Kjeller

KJELLER, headquarters of Norway's Institutt for Atomenergi, has not hitherto widely circulated its periodic progress reports and, except for a few brief news items and references in our previous Continental Review (*Nuclear Engineering*, December, 1960, p. 544) little has been published in these pages since February, 1959 (p. 64), when a brief description was given. Progress reports are now being more widely circulated.

The natural uranium heavy water moderated reactor Jeep is still operating satisfactorily and, during the period covered by the present report (January/March, 1961), operated at a steady thermal power of 450 kW for a total of 26 MWd, with routine shut-downs for isotope removal and replacement. Additional shielding has been installed to improve working conditions around the reactor block and reduce radiation levels in the reactor hall; new ventilation arrangements in the control room have given more constant working temperatures for the instruments.

The design of Jeep II, a heavy-water reactor with slightly enriched fuel, is still under review, with the object of reducing costs by simplifying design. The possibility of introducing a flux-trap, to improve peak flux values, was investigated, and consideration was given to the possibility of spectral-shift as a means of long-term reactivity control. As the design at present stands, the core is ring-shaped, with inner and outer diameters of 14 cm and 40 cm respectively, giving an active core volume of about 300 litres. The peak neutron flux would be about 4×10^{13} n/cm²s at 2 MW; the fuel loading some 400 kg of 3% enriched UO_2. The moderator would be a D_2O/H_2O mixture, with about 20% H_2O.

Although not specifically stated in the report (which covers the period ending March 31) the zero-energy facility Nora was put into operation on June 9. This facility is to be operated in conjunction with the IAEA on a joint research programme.

The Rederiatom nuclear ship studies have continued, with emphasis on boiling water reactor dynamics and hydraulics, and studies of plant contamination under normal and adverse conditions. Work has been carried out on modifications to the original Rederiatom design, which was for a rather conservative indirect cycle system; the revised plan proposes a direct steam cycle with coolant recirculated through two subcooling loops, each containing a secondary steam generator. The secondary steam would be used for auxiliary machinery. A design study is in its preliminary stages for an oceanographic research vessel which, in addition to high speeds, would allow long times at sea without entering harbour. The reactor considered is based on the spectral-shift concept, with in-core superheat.

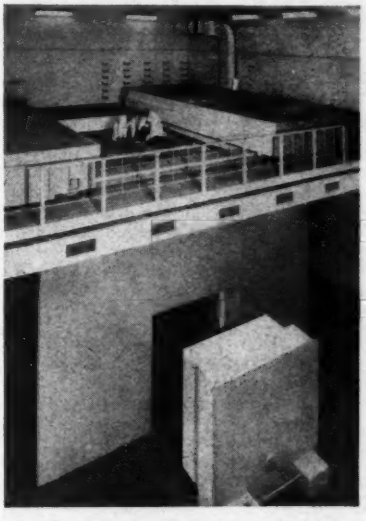
The neutron physics programme, largely undertaken in conjunction with the Netherlands, has included work on neutron diffraction, positron annihilation and plutonium determination by X-rays, this latter being part of a research contract with IAEA to see if X-ray fluorescence analysis can be used to determine the amount of plutonium formed in an irradiated fuel element.

Fuel element work can be divided into ceramics (sintering of UO_2 and ThO_2) corrosion work and canning techniques, including argon spot welding. Experimental work on the use of spot-welded spacers in stainless steel fuel clusters has shown that it was possible to weld 0·5 mm strips to a tube of 0.25 mm wall thickness without damage.

In connection with the fuel reprocessing pilot plant (another Netherlands-Norwegian project) the fuel rod decanning machine has been redesigned and tested, and shielding for the complete plant has been completed. A number of "dummy runs" with unirradiated material, have been carried out. Research relating to reprocessing includes the chemistry of plutonium, ruthenium and protactinium, amine extraction and plutonium spectroscopy.

In the field of isotopes, production continues in Jeep (maximum flux 1·6 x 10^{13} n/cm²s) but remaining operations have been transferred to the new isotope laboratory. Isotope shipments totalled 267 to outside customers; 167 service irradiations were made for the Institute's own purposes. Industrial applications of isotopes include a full-scale tracer investigation of dust precipitation in a cement factory.

Health physics has mainly been a matter of routine, although improvements are being made in a more extended programme of evironmental monitoring, including a detailed mapping of radiation levels in order to determine the contribution of argon-41 from Jeep to the natural background.



Nora

The Netherlands - Norwegian Reactor School has now been equipped with a reactor simulator to work in connection with the analogue computer and a boiling loop for demonstration of stability in boiling heat transfer. The reactor school is being extended by the addition of an experimental hall and a library-auditorium. Other building work in progress includes new workshops and a mechanical laboratory.

The number of persons employed at the end of the period under review was 567, of which 397 were at Kjeller itself, 160 at the Halden project and 10 assigned to the Dragon project in England and to the RCN at Petten.

TRANSLATIONS

Le programme de recherches d'Euratom. (449)

Le programme de recherches d'Euratom est actuellement en cours de réalisation. Il est passé en revue par les chefs des différents départements intéressés. L'évènement le plus spectaculaire a été l'ouverture du centre d'Ispra où l'intérêt est centré sur le système de réacteur à réfrigérant organique et modéré à l'eau lourde. Le programme conjoint d'Euratom et des Etats-Unis est également en voie de réalisation. Il porte l'accent sur la mise au point des éléments de combustible. Récemment, il a été étendu au financement de la construction des centrales nucléaires, ce qui avec les recherches dans le domaine de la propulsion nucléaire des navires a considérablement étendu le champ des activités d'Euratom.

Dragon. (454)

Durant les derniers douze mois les travaux de construction sur le chantier, à Winfrith, ont avancé très rapidement et près de 80% du béton a été coulé. L'étudu système de purification du gaz a été achevée et un nombre considérable de recherches entreprises. Des changements ont été apportés à l'installation où les éléments de combustible seront placés dans leur container, elle est située maintenant en dehors de la cuve du réacteur; les soudures étanches ont été éliminées. Les éléments de combustible ont été également passablement modifiés. L'article passe en revue ces changements et d'autres modifications.

Réalisations françaises. (459)

Pour la première fois, nous sommes à même de publier certains renseignements relatifs aux principales caractéristiques d'EDF 3, le réacteur gaz-graphite en cours de construction actuellement, à Chinon à proximité d'EDF 1 et d'EDF 2. La principale diférence de ce réacteur avec les précédents réside dans le fait que la cuve du réacteur sera construite en béton précontraint. Dans ce but, il a été nécessaire de mettre au point des dispositifs de mise en tension des câbles très compacts, de façon à pouvoir disposer les câbles de tension suivant un réseau triangulaire ét à donner à l'ensemble la forme d'un fût. Nous avons également la possibilité de donner quelques détails relatifs au projet conjoint franco-belge de Chooz, à la suite de la signature de l'accord entre les parties contractantes. En outre, les programmes de développement les plus importants, tels que ceux d'ELA sont passés en revue.

L'industrie et les brevets. (466)

Le développement de l'industrie nucléaire sur une échelle internationale ne pourrait qu'être favorisé si les nombreuses communités nucléaires adoptaient une politique commune en matière de brevets. Cet article spécial met en relief les politiques différentes déjà adoptées par Euratom, le commissariat américain à l'énergie atomique et son homologue britannique.

Panorama européen. (472)

Des contributions spéciales d'Allemagne, de Italie, de Norvège, etc., font le point des réalisations dans ces différents pays. Dans certains cas, les changements effectués ces derniers mois se rapportent à des détails; dans d'autres cas, il s'agit de changements fondamentaux dans les attitudes.

Tour d'horizon des industries. (487)

Pour la deuxième année de suite, "Nuclear Engineering," présente un tour d'horizon des compagnies européennes, qui s'intéressent au développement de l'énergie atomique. Ce panorama comporte deux sections: l'une consacrée à une liste d'adresses, l'autre à une classification. Une innovation a été apportée cette année: un système de renvoi d'une section à l'autre a été mis au point.

Das Euratom-Forschungsprogramm. (449)

Diese von Abteilungsleitern der Euratom besorgte Zusammenstellung gibt eine Übersicht über das jetzt anlaufende Forschungsprogramm. Das bedeutendste Ereignis war zweifellos die Eröffnung der Ispra-Forschungsstelle mit dem Schwergewicht auf dem organisch gekühlten, schwerwassermoderierten Reaktorsystem. Das vorwiegend auf die Entwicklung der Brennstoffelemente gerichtete Euratom-amerikanische Gemeinschaftsprogramm kommt ebenfalls in Gang und hat zusammen mit der vor kurzem beschlossenen Hilfeleistung bei der Finanzierung von Kraftwerkbauvorhaben und Schiffsreaktorforschung das Tätigkeitsgebiet der Euratom bedeutend erweitert.

Dragon. (454)

Während der letzten zwölf Monate haben die Arbeiten auf der Baustelle in Winfrith grosse Fortschritte gemacht und über achtzig Prozent der Betonkonstruktion ist fertiggestellt. Die Konstruktion der Gasreinigungsanlage wurde abgeschlossen und eine beträchtliche Anzahl von Versuchsprojekten begonnen. Vorgenommene Konstruktionsänderungen beziehen sich u.a. auf die Bewegungsvorrichtung der Bestrahlungseinrichtung ausserhalb des Druckkessels und auf die Vermeidung von Schweissdichtungen. Auch die Brennstoffelemente wurden wesentlich geändert. Diese und andere entwicklungsmässige Änderungen werden im einzelnen besprochen.

Entwicklungen in Frankreich. (459)

Wir können erstmalig in grossen Zügen die Konstruktion des graphitmoderierten, mit CO_2 gekühlten Reaktors EDF-3 angeben, der gegenwärtig von der E.D.F. neben den bereits bestehenden beiden Anlagen in Chinon errichtet wird. Im Gegensatz zu seinen Vorgängern besitzt der neue Reaktor einen Druckkessel aus Beton. Dies wurde dadurch ermöglicht, dass es gelang, Spannseile mit ausserordentlich klein dimensionierten Enden herzustellen, mit deren Hilfe ein Dreiecks-Gitterwerk aus Vorspannseilen im oberen und unteren Teil des Kessels und ein Tonnenflechtwerk im Mittelteil gebildet werden konnte. Wir können weiter Konstruktionseinzelheiten des französisch-belgischen Gemeinschaftsprojekts in Chooz bringen, nachdem vor kurzem der Vertrag mit den Baufirmen unterzeichnet wurde. Ausserdem wird über die wichtigeren Forschungsprogramme, u.a. das EL-4 Projekt, berichtet.

Industrie und Patente. (466)

Es würde für die Entwicklung der Kerntechnik im internationalen Rahmen von grossem Nutzen sein, wenn die einzelnen Gruppen sich über eine gemeinsame Patentpolitik einigen könnten. Der vorliegende Artikel stellt die Gegensätze in der gegenwärtig von Euratom, von der amerikanischen AEC und der britischen AEA verfolgten Praxis heraus.

Europäische Übersicht. (472)

Spezialberichte aus Deutschland, der Italien, Schweden und Norwegen geben Zusammenfassungen der dortigen Entwicklungen. In einigen Fällen beziehen sich die in den letzten zwölf Monaten zu verzeichnenden Veränderungen lediglich auf Einzelheiten; in anderen ist eine grundsätzliche Änderung der Einstellung zu bemerken.

Kernindustrie auf dem Europäischen Kontinent. (487)

Zum zweiten Mal bringt die "Nuclear Engineering" eine Jahresübersicht über die an der Entwicklung der Kerntechnik beteiligte europäische Industrie. Das Verzeichnis besteht aus zwei Teilen, einem Anschriftenverzeichnis und einem Branchenverzeichnis; als Neuerung wurde in diesem Jahre ein Kreuzverweis zwischen den beiden Teilen eingeführt.

El Porvenir de la Industria Nuclear en Europa. (449)

Este artículo constituye una apreciación personal de la situación actual de la industria en Europa continental en relación con los principales desarrollos nacionales e internacionales. Se deduce que, aun cuando el período de crecimiento es probable que sea largo, una vez que se haya alcanzado el punto álgido económico, será rápido el aumento de actividad. Se señala la influencia del plutonio en la tecnología europea y la importancia consiguiente de saber como manejar esta substancia intransigente.

Dragon. (454)

Durante los últimos 12 meses ha progresado rápidamente la construcción en Winfrith habiéndose terminado ya más o menos el 80% de las obras de hormigón. También está terminado el proyecto del sistema de purificación de gas y se han iniciado numerosos proyectos experimentales. Las modificaciones de diseño comprenden el movimiento del sistema de enfundadura del elemento irradiado desde fuera del recipiente a presión, y la eliminación de soldaduras de cierre hermético. También se han llevado a cabo modificaciones importantes en los elementos combustibles. Se pasa revista a estos y otros cambios evolutivos.

El Desarrollo en Francia. (459)

Por primera vez podemos publicar planos de contorno del EDF-3, el reactor con moderador de grafito y enfriamiento por CO_2, que la E.D.F. está construyendo al lado de sus otras dos instalaciones en Chinon. La característica sobresaliente de este reactor es que, a diferencia de sus antecesores, el recipiente a presión es de hormigón. El factor crítico ha sido el perfeccionamiento de cajas cabeceras de cables de tamaño extraordinariamente reducido que han permitido dotar los extremos de una celosía triangular de cables de pretensado y dar al cuerpo forma de barril. También podemos dar detalles de la concepción del proyecto franco-belga en Chooz, como resultado de la firma reciente del acuerdo con los contratistas. Además se pasa revista a los programas más importantes de investigaciones tales como el EL-4.

La Industria y las Patentes. (466)

El desarrollo de la ingeniería nuclear en una escala internacional podría favorecerse si las diversas comunidades nucleares adoptase un criterio común sobre patentes. Este artículo especial contrasta los diversos criterios ya adoptados por Euratom, la AEC de los EE. UU. de A. y la AEA del Reino Unido.

Noticiario Europeo. (472)

Informes especiales de Alemania, Suiza, Italia y Noruega resumen los acontecimientos de interés en estos países. En algunos casos los cambios efectuados durante los últimos 12 meses han sido de cetalle únicamente, mientras que en otros pueden apreciarse cambios fundamentales de actitud.

Revista de las Industrias Continentales. (487)

Por el segundo año sucesivo "Nuclear Engineering" presenta una revista de la industria en Europa que está contribuyendo al desarrollo de la ingeniería nuclear. La lista se presenta en dos partes, una sección de direcciones y una sección clasificada, siendo este año una novedad el hecho de que en cada sección se halla referencia a la otra.

Personal

Appointments—U.K.

Sir William Strath, Mr. W. Hackett and **Mr. R. D. Young,** as managing directors of Tube Investments. They retain their former individual responsibilities within the group. Sir William, for instance, is still managing director of British Aluminium, which he was appointed earlier this year. The appointment of the triumvirate follows the relinquishment of the post of managing director by **Sir Ivan A. R. Stedeford,** who remains chairman.

Sir Donald Perrott, deputy chairman of Dewrance and Company, as chairman, and **Mr. J. B. W. Cunningham,** managing director of the AEA engineering group, as managing director. Sir Donald, who was until July, 1960, AEA member for Finance and Administration, succeeds **Sir Eric Mieville,** who is retiring. Mr. Cunningham, who takes up his new duties next January, fills a vacancy caused by the retirement earlier this year of **Mr. J. M. Storey,** which has been temporarily filled by Sir Donald Perrott. It is his second appointment with Dewrance, having been assistant works manager from 1939-44.

Mr. J. D. Glanville, director of supply services, AEA engineering group, to the board of Richardsons, Westgarth and Company with responsibilities as group production director. **Mr. H. Watson-Jones,** managing director of Richardsons, Westgarth (Hartlepool), as group commercial director.

Dr. J. W. Menter, team leader at the Tube Investments Research Laboratory, Hinxton Hall, Cambridge, as director of the laboratory. He succeeds **Dr. T. P. Hughes,** who was not, as stated in last month's issue, TI director of research. **Dr. J. M. Kay,** the new TI director of research and development, succeeds **Sir Ben Lockspeiser.**

Mr. R. B. W. Bolland

Dr. J. W. Menter

Mr. H. V. Disney, deputy managing director of the AEA engineering group, as managing director.

Sir Willis Jackson, director of research and education AEI (Manchester), as professor of electrical engineering at Imperial College of Science and Technology, London. He has also been appointed to the Government's Advisory Council on Scientific Policy.

Mr. H. Weston Howard, managing director of Hayward Tyler as chairman, and **Mr. A. C. Ball,** formerly works manager at the company's East Kilbride factory, and more recently manager at Luton, as managing director.

Sir William Strath

Sir Donald Perrott

Mr. J. B. W. Cunningham

Mr. H. V. Disney

Mr. A. C. Main, director of manufacture, AEI (Manchester), to the newly created post of director of manufacturing services, AEI.

Mr. G. Cunliffe, managing director of Norcros, the industrial holdings company, as president of the British Standards Institution. **Sir Anthony Bowlby,** a director of Guest, Keen and Nettlefolds, becomes chairman of the Institution's engineering divisional council.

Mr. J. D. Eccles, as director and general manager of Head Wrightson Stockton, and **Mr. R. B. W. Bolland,** formerly general manager, as London manager of the parent company, Head Wrightson. Also announced —**Mr. G. F. Taylor,** as general manager of Head Wrightson Steel Foundries and **Mr. A. J. Long,** as general manager of the Head Wrightson Export Company.

Mr. Jack White, formerly with Mullard in the commercial section, as sales administration manager of Texas Instruments.

The Plessey Company have announced the appointment of **Brigadier J. D. Haigh,** divisional manager for capacitors and resistors, as general divisional manager in charge of wiring and connectors, capacitors and resistors, and of the subsidiary company, Preformations. **Mr. R. L. Higgins,** commercial executive of the components group, becomes general manager of the group, and **Mr. A. A. Evans,** a regional sales administrator, is appointed sales manager of the capacitors and resistors division.

Mr. S. H. Ireland, assistant managing director of the Consolidated Pneumatic Tool Company, as managing director. He succeeds **Mr. Norman Readman,** who has become chairman.

Mr. L. Barton, Mr. A. B. Crompton, Mr. G. L. Jaques, and **Mr. L. Winstanley,** engineering executives with Matthews and Yates, to the board.

Mr. F. T. Jones, production manager of Hunting Aircraft, to the board of Microcell. **Mr. J. A. Grace,** manager of the sales and commercial division, de Havilland Aircraft, as commercial director.

Mr. J. D. Glanville

Sir Ralph Cochrane

Mr. R. I. Douglas, as export sales manager of Permali.

Mr. J. Waddell, executive director of Turner Brothers Asbestos Company, as managing director. He has also been appointed managing director of Glass Fabrics, an associated company.

Mr. L. H. Welch, who retired recently from the post of chief electrical engineer to the London Electricity Board, has been appointed as industrial relations consultant to the Electrical Research Association.

Dr. D. S. Beard, formerly a lecturer in physics and mathematics at Norwich City College, as technical sales director of Griffin and George (Sales).

Mr. D. Ambrose, manager of the laboratory engineering department of Automatic Control Engineering, as southern manager for Fischer and Porter.

Mr. D. E. Haynes, secretary of Hawker Siddeley Aviation, as secretary of Bristol Siddeley Engines. He succeeds **Mr. F. Shutt,** who has been appointed financial comptroller of Hawker Siddeley Industries.

Overseas

Mr. B. Aabaken, as head of the technical secretariat of the Institutt for Atomenergi at Kjeller, Norway, and also executive secretary of the Norwegian atomic energy council. He was formerly technical secretary of the ENEA Dragon reactor project, a position now occupied by **Mr. R. G. M. Hedlund,** previously personal assistant to Dr. Eklund in Sweden.

Dr. Ira F. Zartman, chief of the reactor physics branch in the U.S.AEC division of reactor development, as AEC representative in Tokyo, and **Mr. Robert W. Ritzmann,** chief of the planning section in the evaluation and planning branch of the Commission's reactor development division, as representative at Chalk River.

Mr. F. R. Bruce, director of radiation safety and control at Oak Ridge, to the newly created post of assistant deputy director.

Dr. Henry Gomberg, director of Michigan University's nuclear energy research programme, as deputy director of the Puerto Rico Nuclear Centre.

Retirements

Sir Ralph Cochrane, from Rolls-Royce. With the company since 1956, he was in charge of the research laboratory with overall responsibility for policy and future programmes.

Sir Francis Evans, from the board of Dewrance and Company.

Rear Admiral J. G. C. Given, from the board of Richardsons, Westgarth and Company.

Industrial Notes

A contract for the supply of an **IBM** "Stretch" computer to be installed at the AWRE, Aldermaston, has been signed. Delivery will probably take place during 1962. The AEA already have three smaller IBM computers in operation, one at Aldermaston and two at Risley.

A new production shop for the manufacture of electric arc welding equipment and a two-storey office block have been built at the Waltham Cross works of **Murex Welding Processes** for about £350 000. The shop is a 500 ft long single-storey building providing 62 000 ft³ of uninterrupted floor space. The office block, which has a 7 200 ft² floor area, will accommodate the plant sales department, drawing office and works engineer's department.

An additional feature of the Power Generation and Clean Air Equipment Exhibition to be held at Olympia, London, May 4-11, 1962, will be Britain's first Space Research and Technology Exhibition. The organizers, **Provincial Exhibitions,** feel the inclusion of the new exhibition is appropriate in view of the impact of space research on engineering developments and its association with the new trends in fuel utilization and power generation. It will be sponsored by the **British Interplanetary Society,** the main exhibition being sponsored as in previous years by the **Institute of Fuel.**

Firth Cleveland Instruments are to supply tank level gauging equipment for the *Dreadnought*. It will be the 42nd submarine for which they have supplied their well-established "Pacitor" equipment for use in the ballast and fresh-water tanks.

A European Lead Development Committee has been formed following meetings in Rome between representatives of the French, German, Italian, Spanish and United Kingdom lead associations and Belgian and Swedish lead producers. The Lead Development Association, London, will be responsible for the secretarial work of the new committee under a steering group comprising France, Germany, Italy and the U.K. One of the first activities of the committee will be the organization of an International Conference on Lead to be held in London, May 22-25, 1962. Nuclear shielding will be among the subjects to be covered by the conference.

E. G. Irwin and Partners, the engineering consultants, expect to move to their new headquarters, Irwin House, Southwark Street, London, S.E.1, by December.

Metal Industries are setting up a new company in Canada. To be known as Dominion M.I. and with headquarters and works in Montreal, it will be concerned with the promotion of MI products in the Canadian market and the manufacture of specialized electrical control systems and equipment.

The film, "The Winfrith Pipeline." showing the construction and laying of the Winfrith effluent pipeline two miles out to sea, is now available from the **COI Central Film Library.**

A portable British Oxygen pipe cutting machine being used for bevel cutting a Trawsfynydd boiler. These machines are normally used for cutting pipes up to 3 ft dia., and in this case the cutter had to be specially set up on a 53-ft-long circular chain rig. The blowpipe was set to give a 15° bevel finish ready for automatic electric welding. One cut was made in 70 min.

A two-month tour of France, West Germany, Italy, Switzerland and Yugoslavia is being made by the **Avo** mobile demonstration unit which carries samples of the full range of Avo electrical and electronic equipment.

Meetings at which experts from various European countries will discuss the markets in their own countries with British businessmen are being arranged by the **London School of Marketing.** The first takes place October 30-31 and will be attended by three specialists from France. Later meetings will deal with Germany, Italy and the Scandinavian countries. Details are available from Newspaper House, Great New Street, London, E.C.4.

The oldest working oxygen cutting machine manufactured by **Hancock and Company (Engineers)** was recently presented to the Birmingham Museum of Science and Industry. Made in 1924, it has been in constant use at the factory of a Wolverhampton company and won first prize in a competition organized by the manufacturers at the Welding Exhibition at Olympia earlier this year. The prize was a new profiling machine.

Compagnie Generale de Telegraphie Sans Fil, of Paris, are to supply a linear accelerator for installation at the Central Nuclear Measurements Bureau set up by Euratom at Geel, Belgium. It will be capable of providing a 26 × 10" n/s flux. Installation of the machine is expected to be completed by November, 1963.

Electronic Associates have established a wholly owned subsidiary at Aachen, West Germany. At the same time they have announced the sale to Interatom, Bensberg, near Cologne, of two "Pace" 231R computers at a cost of about £50 000.

Vitro Engineering Company have been awarded a design and engineering contract for a rocket engine maintenance and disassembly building to be built at the National Nuclear Rocket Development Center, Jackass Flats, Nevada.

A pilot plant for the compaction of uranium oxide and boron carbide powder into fuel and control rods by vibratory means is being set up by **General Electric** at their San Jose establishment. It will be used for the fabrication of some of the fuel for the 12·5 MW BWR and light water critical assembly being supplied to Japan, as well as for the production of prototype fuel elements.

Combustion Engineering have been awarded two contracts by the U.S.AEC for fuel for the Bonus power station under construction in Puerto Rico. The first is for the supply of 36 fuel assemblies made up of uranium enriched to 3.5% for the superheater zone of the reactor and the second for 74 assemblies enriched to 2.4% for the boiler zone. Total value of the contract is $900 150. Delivery is required within about 11 months.

Cawkell Research and Electronics have moved their offices to 99 Uxbridge Road, Ealing, London, W.5. Telephone numbers are Ealing 6215 and 7585.

Racal Engineering have changed their name to **Racal Electronics.**

The Pioneer Oilsealing and Moulding Company have moved to new premises at Barrowford, Nelson, Lancashire. Telephone number is Nelson 62241 and the Telex 63122.

MEETINGS

November 6.—Institute of Marine Engineers, at the Liverpool Engineering Society, at 6 p.m. **Observations on the Design and Construction of n.s. "Savannah,"** J. A. Dodd and S. Macdonald.

November 9.—Liverpool Metallurgical Society. **Metallurgical Aspects in the Development of Fast Fission Reactors,** C. R. Tottle.

November 13.—Institute of Metals (Scottish Section), at the Institution of Engineers and Shipbuilders, Glasgow, at 6 p.m. **The Effects of Irradiation on Materials,** H. M. Finniston.

November 15.—Institution of Mechanical Engineers, at Westminster, at 6 p.m. **The Influence of Gas-Inlet Temperature on Magnox Reactors,** a discussion.

November 20.—Institute of Physics and Physical Society (Manchester Branch), at the College of Science and Technology. **Neutron Diffraction,** by G. E. Bacon, AERE, Harwell.

November 21.—Institution of Civil Engineers, at Westminster, at 5.30 p.m. **The Main Building for the 7 GeV Proton Synchrotron at Harwell,** S. A. Rossiter and J. S. Brown.

November 22.—Manchester Metallurgical Society, at the Literary and Philosophical Society, George Street, at 6.30 p.m. **Metallurgy of the Rarer Metals,** J. C. Chaston.

November 28.—Institute of Marine Engineers, at the Memorial Building, Mark Lane, London, at 5.30 p.m. **High Temperature Gas Cooled Reactors for Marine Propulsion,** J. E. Richards.

December 13.—British Institution of Radio Engineers (Merseyside Section), at the Walker Art Gallery, Liverpool, at 7.30 p.m. **Nuclear Power Station Instrumentation,** M. W. Jervis.

December 13.—Institution of Electrical Engineers, in conjunction with B.N.E.C., at Savoy Place, London, at 5.30 p.m. **Electrical Aspects of Hunterston Nuclear Generating Station,** J. Henderson, G. F. Kennedy, and K. J. Wootton.

Processes and Equipment

For further information on any item please enter the relevant number on one of the Reader Service Cards enclosed with this issue.

(Right) Travelling-bridge type electro-hydraulic manipulator.

(Below) Three movement hydraulic arm.

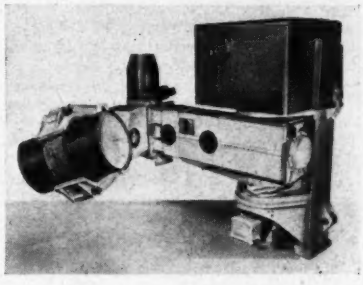
Remote Handling Mechanisms

The S.O.M. (Paris) range of remote handling mechanisms contains several hydraulic devices suitable for nuclear work of various types.

The simplest device in the range is a hydraulic arm, suitable for direct hydraulic control, although electro-hydraulic control can be applied if desired. It has three movements; continuous rotation of the arm from 0·2–5 rev/min; continuous wrist rotation from 0·5–15 rev/min; elbow movement of 10°–93°. The jaws, which have a capacity of 50 kg (approx. 1 cwt) can be replaced by a hook having a capacity of up to 100 kg. The arm may be fixed directly to a bulkhead, etc., or may be mounted on a travelling bridge, crane, or elevating carriage if other movements are desired. Power requirements are of the order of 8 litre/min. (1·76 gal/min) at 100 kg/cm² (1 422 psi).

A more sophisticated design, as supplied to the irradiated fuel laboratories at Saclay, is mounted on a travelling crane bridge, and has six electro-hydraulic movements in addition to the jaw grip. In addition to the long travel and cross traverse movements of the arm (5–50 mm/s) the arm can be raised (with a load of 500 kg (approx. ½ ton)) or lowered about 1·1 metre and continuously rotated at 0·5–10 rev/min. An elbow movement of 5°–95° is provided, with continuous wrist rotation at 0·5–30 rev/min. The jaw load is 100 kg.

Finally, there is a heavy-duty (300 kg) manipulator intended for mounting directly on a bulkhead or on a rising carriage. This



Heavy-duty hydraulic manipulator

has a horizontal arm movement of 180° total, while the elbow joint has a total movement of 250°. The arm has a telescopic movement and the wrist is arranged for continuous rotation. The jaws have a lifting capacity of 300 kg and a maximum opening of 500 mm (approx. 19·8 in).

(Société d'Optique et de Mécanique de Haute Précision, 125 Boulevard Davout, Paris 20e.)

1147

Digital Radiation Measurement

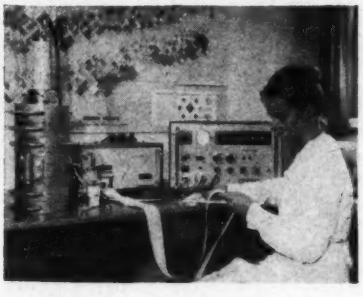
Illustrated is a complete counting station made up of standard Telefunken units, including a lead-shielded scintillation counter unit, the necessary timing, amplifying and counting unit, with a digital printer.

The company has recently developed a number of new devices, including an anti-coincidence measuring head and a mercury/lead screening unit, intended for measurement of very low activities with large scintillation crystals. The use of a 20 mm mercury layer assists in suppressing the characteristic radiation of the 50 mm lead screen, giving very low background count with relatively low weight.

(Telefunken GmbH, Berlin-Charlottenburg 1.)

1148

Telefunken counting equipment (see text).



Cooling Blocks

The Peltier effect (cooling of a junction between two dissimilar conductors) has been utilized by S.A.C.M. in the production of cooling blocks or slabs which are commercially available for a number of practical applications. Two sizes are at present being manufactured, for dealing with thermal loadings of 5 W and 1 W, having dimensions of 47 × 47 × 13 mm and 45 × 23 × 7 mm respectively. Each consists of a series of semi-conductors of n and p types connected in series by metal bridges arranged so that all the "cold" junctions are on one side of the slab and all the "hot" junctions are on the other. The slab is then placed in contact with the device which it is desired to cool (in the case of an enclosure of any size, it would be possible to apply a number of slabs).

Power requirements of the two sizes are approximately 30 W (30 A 1V) and 6 W (3 A 2 V) d.c. or rectified current with not more than 10% ripple. With their rated thermal loadings (5 W and 1 W) temperature differences of 60°C and 40°C respectively are possible, with the "hot" face at 100°C.

(Société Alsacienne de Constructions Mécaniques, 69 Rue de Monceau, Paris, 8e.)

1149

Portable Radiation Monitor

The Graetz Raytronic X500 pocket radiation monitor has a number of interesting features. Capable of measuring beta or gamma radiation (or alpha particles with an additional head) it is compact (143 mm × 97 mm × 43·5 mm or approximately 5·6 in × 3·8 in × 1·7 in) and light in weight (560g or, roughly 1¼ lb). Battery operated, it has provision for connection to a battery charger (supplied as an accessory) which can be used as a direct supply for stationary work.

Four scales are provided, which are arranged in drum formation so that the scale is changed at the same time as the circuit.

Graetz portable monitor with probe and earphone.

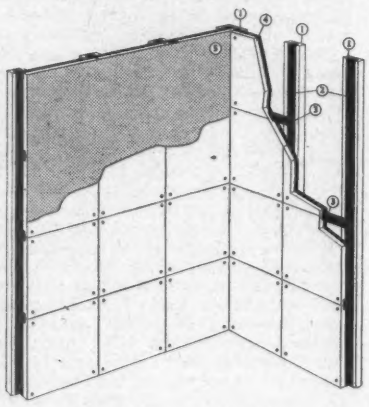
The scales cover from 0-10 mr/h and 0-1 count/s on the lowest range to 0-500 r/h and 0-4 000 count/s on the highest. The case is in a polyamid plastics material and is watertight (test 1 hour at 50 cm w.g.). The instrument is claimed to be vibration proof up to 10 *g* and shock-proof (with the exception of the meter tube) up to 25 *g*. Auxiliary earphones for audible counting of particles can also be supplied.

(Graetz-Raytronik GmbH, Altena, Westfalia.)

1150

Radiation Screening Panels

For X-ray and low-energy gamma-ray work, where radiation levels are not high enough to require a wall of lead bricks, a most convenient method appears to be the Pan-O-Plomb system developed by a Brussels company, in which the shielding is



Pan-O-Plomb screening panels. 1, vertical framework; 2, vertical masking strips; 3, horizontal masking strips; 4, panels; 5, paint or other finish.

built up from standard panels on a framework.

The panels themselves consist of the necessary thickness of lead, bonded to chipboard, or other material, each panel being secured to the framework by wood-screws. Radiation streaming at the joints is prevented by lead plate strips let into the panels for the horizontal joints; the vertical joints are similarly masked by lead strips let into the framework uprights and the fixing holes are provided with lead bushings and plugs. Test radiographs show that, so far from allowing leakage, the joints have a larger equivalent thickness than the panels themselves.

The panels have undergone severe climatic tests under cyclic variation of temperature and humidity. Any form of painting or enamelling may be applied after assembly.

(Compagnie des Métaux d'Overpelt-Lommel et de Corphalie, S.A., 54 Rue des Fabriques, Brussels.)

1151

Moving Coil Relay

A French range of sensitive relays now being marketed in Britain will operate on currents at low as 1 μA, and rectifiers or thermocouples may be incorporated for

Miniature sensitive relay.

a.c. work. Double-wound coils can be provided for differential deflection. Contacts may be provided for 1-make 1-break or 2-make, as desired, and the movement may be centre-stable or end-stable. The position of all contacts is shown on an instrument-type scale at the end of the relay; screw-heads are provided for adjustment of the fixed contact positions.

The size of the relay is 1½ in (38 mm) diameter x 3¼ in (83 mm) long, and it is designed to plug into a standard international octal valve holder.

(Albert le Boeuf et Fils, Colombes. British and Commonwealth concessionnaires, L. E. Simmonds, Ltd., Byron Road, Harrow, Middlesex.)

1152

Leak-testing Equipment

A brief description of the CFTH mass spectrometer equipment for leak detection work was given in *Nuclear Engineering* for May 1960, p. 233, and it is now possible to give further particulars of the remainder of the plant.

The actual detection of leaks takes place, of course, by exposing individual elements in vacuum chambers to the spectrometer, but there is considerable interest in the pre-testing process in which the elements are exposed to helium under pressure so that helium may enter through any permeable portions of the sheath. Since the number of fuel elements to be tested is usually large, and several hours immersion in helium is required, this process is usually carried out in a number of chambers, each taking several elements. The chambers are arranged in banks and are designed to withstand vacuum as well as pressure; exhaustion of air prior to application of helium under pressure avoids contamination of the helium which, after the immersion process, can be pumped off for recycling, thus effecting considerable savings in running costs. Safety in operation is assured by interlocking of the helium valves with the covers of the chambers, and preventing the covers being raised when the chamber is pressurized.

(Compagnie Francaise Thomson-Houston, 173 Boulevard Haussmann, Paris 8e. Leland Instruments Ltd., 145 Grosvenor Road, London, S.W.1.)

1153

CO Detector

Of Danish origin, a new carbon monoxide detector is now being manufactured in Britain. It consists of a plate 5 cm square

Herzbi CO detector before and after exposure.

of plastics material, with a disc insert of palladium chloride suspended in silica gel. Blackening of the disc, due to the reduction of the chloride, takes place to a greater or

CFTH immersion chambers for testing fuel elements at Marcoule.

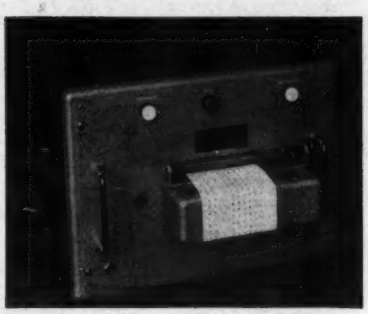
lesser degree on exposure to a CO-contaminated atmosphere, according to the concentration. Detection is said to be practically immediate with 0·05% CO, and to take approximately 5 min with 0·02%, or less than 15 min with 0·01%. The blackening fades after a comparatively short time (20 min-3 hours depending on exposure) in a non-contaminated atmosphere, the life being approximately one month in service, although the "shelf life," in sealed container, is considerably longer.

(Herzbi Ltd., 57 Lordship Park, London N.16.)

1154

Electromechanical Printer

Of German origin a new range of electromechanical printer equipment is now available in Britain. Simple and robust, it is of



Wetzer electromechanical printer.

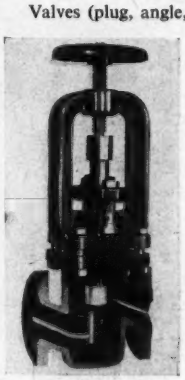
unit construction so that it is readily adaptable to any specific requirements. Counting units and type wheels are available in groups of 2, 4, 6 or 8 and may be arranged to print added results, consecutive numbers, date, time, etc. The unit illustrated has two groups, one 2-digit for consecutive counting and a 6-digit group for printing information received from the input circuits. Either free-standing or rack-mounted units can be supplied.

(Hermann Wetzer K.G., Bavaria. General Precision Systems Ltd., Bicester Road, Aylesbury, Bucks.)

1155

Corrosion Protection

Valves (plug, angle, globe, gate) and sight flow glasses can now be obtained in Britain lined with Bascodur, a German



Angle valve cut away to show Bascodur lining.

development by Eisenwerk Rodinghausen, Lendringsen Krs., Iserlohn.

Bascodur has a carbonaceous base, agglomerated with a thermo-setting resin, is highly resistant to acids, alkalis and solvents and is capable of withstanding elevated temperatures. It is also claimed to have good performance under shock, flexural and hardness tests.

Tests carried out with cobalt-60 have shown that it withstands gamma radiation up to a dosage of at least 10^9 r, the results of 10 tests having shown that it was practically unaltered—if anything, a trifle harder, after irradiation.

Gate valves of this type are suitable for low-pressure work. Other types, plug, angle, globe, are suitable for pressures up to 150 psi (10·6 kg/cm²) and temperatures up to 300°F (149°C).

(I.V. Pressure Controllers Ltd., Atlas House, 683 London Road, Isleworth, Middlesex.)

1156

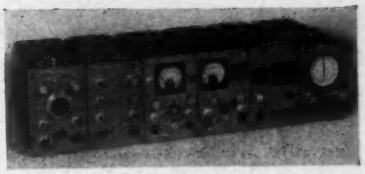
Unit Instrumentation

Printed circuits are used in a new compact series of instruments, developed in conjunction with the U.K.AEA, which features unit construction and standard dimensions for each of the six units comprising the range.

The power unit, in addition to the l.t. supply for the other units, has a continuously variable h.t. supply from 500 to 3 000 V for photomultipliers, G-M tubes, etc. The amplifier unit has an overall voltage amplification of 10^3, with a pre-amplifier stage for high input impedance and three stages of 10 x.

The analyser unit can accept random pulses at 30 000/s and has a channel width continuously variable from 0·2 to 1 V, while the ratemeter has a maximum counting rate of 30 000/s in eight ranges. Below 10 counts/s pulses are counted on an electromechanical counter.

The scaler unit has a resolving time of 1 μs and can store 10^9 counts, readings being on neon lamps up to 10^3 counts, the remaining four digits being shown on an electromechanical register. The timer unit produces ½-s pulses by stop-watch, and elapsed time can be selected from 5 s to 20 000 s.



A bank of the new Nuclear Enterprises' instrument units.

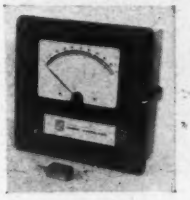
Standard dimensions are 4 in wide × 6 in high × 10 in deep (approx. 101 × 152 × 254 mm) and transistorized construction throughout ensures that heat dissipation is low.

(Nuclear Enterprises (G.B.) Ltd., Bankhead Medway, Sighthill, Edinburgh, 11.)

1157

Position Indicator

Precision indication of the displacement of a shaft, operating mechanism or valve, etc., is given by a new displacement indicator known as the



Genetrol TM-1 position indicator and transmitter

"Genetrol" type TM-1.

The unit consists of a linear-scale instrument and a transmitting potentiometer, which may be linear, multi-turn up to 25 turns, or single-turn up to 358°.

Continuous indication can be obtained

BRIEFLY . . .

Thermocouples for temperatures of up to 4 200°F (2 315°C) are announced by **Honeywell Controls Ltd.**, Greenford, Middlesex. According to the actual temperatures required, combinations of tungsten, rhenium, rhodium, molybdenum, iridium and platinum are used. Other advantages claimed for the new range are improved linearity, higher output and reduced grain growth. **B303**

Duraline, a new hard rubber tank lining, is now being produced by the Chemical Plant Linings Division of the **Dunlop Rubber Co. Ltd.**, Cambridge Street, Manchester. Resistant to vibration and shock, it has been used up to 105°C (221°F) continuously for long periods. **B304**

Sealing of pipe threads should be made much easier by the use of an unsintered PTFE tape being marketed for the purpose by **Turner Brothers Asbestos Co., Ltd.**, of Rochdale, Lancs, in dispensers containing 20, 30 or 40 ft of ½ in tape. Unaffected by ageing or weathering, and suitable for temperatures up to 300°C (572°F), the tape enables the connection to be readily broken when required. **B305**

Alpha Metals Inc., 56 Water Street, Jersey City 4, New Jersey, announces Alpha Vaculoy (R) bar solder, said to be significantly freer from oxide-forming elements than other commercial solders. It is stated that, in printed circuit production, its use has resulted in the reject rate being cut from 8 in 400 to 1 in 5 000. **B306**

A new cobalt-platinum permanent magnet alloy, Platinax II, is announced by **Johnson, Matthey and Co., Ltd.**, 73-83 Hatton Garden, London, E.C.1. With a BH (max) of 9.2 x 10^6 gauss-oersteds, it is said to be one of the most powerful materials known and, before final heat treatment, can be rolled, drawn or machined without difficulty. **B307**

Interlas Ltd., Ampthill, Bedford, are marketing what is claimed to be the smallest heavy-duty argon welding torch ever offered to the industry. Intended for use in confined spaces, the "Tec" weighs only 2.5 oz (71 g) but can be used up to 300 A. **B308**

Pervon, a new addition to the Adcora range of anti-corrosive coatings, has been under development by **E. and F. Richardson Ltd.**, Buckingham, since 1959, and is now being marketed. A polyurethane pitch product, it is said to cure rapidly (even below freezing point), to be unaffected by high humidity during curing. Ferrous surfaces protected with a 10-mil coating have emerged unchanged from a six-month immersion in 20% nitric acid. **B309**

The Dymo embossing tool for labelling identification tapes (*Nuclear Engineering*, November, 1960, p. 529) manufactured by **Hellerman Ltd.**, Gatwick Road, Crawley, Sussex, can now be obtained with interchangeable dies to enable tapes to be lettered horizontally or vertically. **B310**

Lawes Rabjohns Ltd., Abbey House, Victoria Street, London, S.W.1, announce a machine stencil colouring process for maps, plans and diagrams, eliminating repetition colouring by hand, and economical if more than six copies are required. Another development is the production of Admel dyeline papers in a number of tinted base papers, to assist in ready identification of different classes of drawings. **B311**

Bryans Aeroquipment Ltd., 1 Willow Lane, Mitcham, Surrey, have developed a new addition to their range of data handling and plotting equipment. The No. 20040 Curve Follower has an induction head which can follow a curve drawn in conducting ink and will produce a voltage proportional to the "Y" co-ordinate when the appropriate "X" co-ordinate is fed into the plotting table circuit. **B312**

A new ultrasonic thickness gauge, easily portable, which requires access to one side only of the material being measured, has been developed by **Dawe Instruments Ltd.**, Harlequin Avenue, Great West Road, Brentford, Middlesex. It has a thickness range of 0·09 in to 5 in, is direct-reading with steel, copper, and aluminium, and can readily be calibrated for most other materials, such as glass, ceramics and hard plastics. **B313**

from mains-operated instruments; battery operation can be supplied for intermittent reading, if preferred.

(General Controls Ltd., 13-15 Bowlers Croft, Honywood Road, Basildon, Essex.)

1158

Descaling Graphite Tubes

Graphite heat exchangers, as frequently used in chemical plants for difficult fluids, are particularly susceptible to damage when

Cleaning graphite tubes with a small-diameter Vacu-Blast nozzle.

descaled by ordinary methods; in addition, it tends to be a slow process.

The Vacu-Blast closed-circuit system of grit blasting was recently adapted to this duty by the use of an extension lance, fitting into the $\frac{1}{4}$ in dia. tubes of a graphite heat exchanger forming part of an acid evaporation plant. Blasting took place on a controlled cycle of 2 min per tube, the grit being collected from a cone beneath the exchanger by the vacuum integral with the machine.

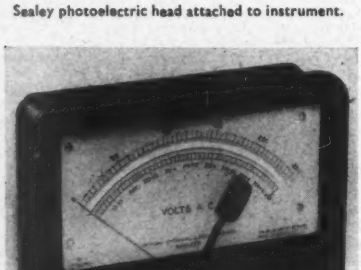
(Vacu-Blast, Ltd., Wellcroft Road, Slough, Bucks.)

1159

Instrument Warning Device

What might be termed a "do-it-yourself kit" for obtaining alarm or control action from a simple indicating instrument has been developed by Stanley Sealey. In essence, it consists of a photoelectric head with a control unit, the "sight" of the pointer initiating the desired control or alarm circuit. The head, which is only $\frac{3}{4}$ in x $\frac{1}{4}$ in x $\frac{1}{4}$ in, can be easily applied to the front of an instrument without obscuring the scale; it can equally well be applied to pen recorders, thermometers, etc., and has been used for monitoring oil globules in tubes, to shut down the plant if the interval between globules becomes excessive.

Sealey photoelectric head attached to instrument.

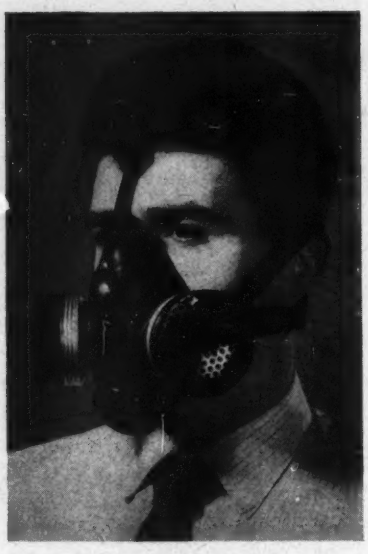


(Sealey Engineering Co. Ltd. (Electro-Mechanical Divison), Ruden Way, Reigate Road, Epsom, Surrey.)

1160

Respirators

Developed in conjunction with the U.K.AEA, a special half-face respirator, supplied in large quantities to Harwell, is



MSA half-face respirator for Harwell.

capable of absorbing both active and non-active vapours. The filter elements have less than 0·05% penetration of the standard methylene blue cloud to BS 2577-1955.

(Mine Safety Appliance Co. Ltd., Queenslie Industrial Estate, Glasgow, E.3.)

1161

Rolling Diaphragms

Where even minute amounts of leakage cannot be tolerated in hydraulic or pneumatic cylinders, it has sometimes been practical to fit a convoluted (bellows-type) diaphragm on short-stroke applications. A new type of rolling diaphragm has been developed

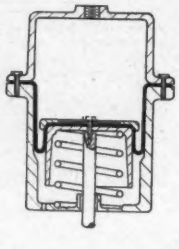


Diagram of Bellofram rolling diaphragm.

which makes it possible to obtain zero leakage on comparatively long strokes; as will be seen from the diagram, the diaphragm will roll from the side wall of the piston on to the cylinder wall, without introducing perceptible friction.

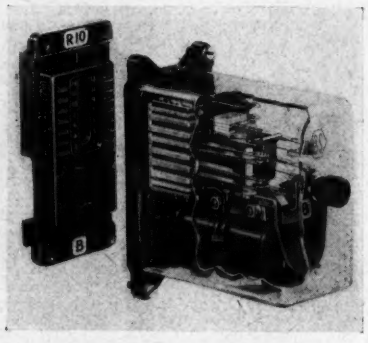
The diaphragms, which are being manufactured under licence from the Bellofram Corporation of Burlington, Massachusetts, are made from "Gaco" synthetic material or silicone rubbers, bonded to fabric reinforcement of rayon, PTFE or glass fibre, according to the temperature conditions, and have little static friction, hysteresis or spring. Their use often enables economy in manufacture due to the elimination of the very close tolerances otherwise required.

(George Angus and Co., Ltd., Coast Road, Wallsend, Northumberland.)

1162

Fleeting-contact Relay

Mounting of a small auxiliary relay inside a standard type of Clifford and Snell, Ltd., plug-in relay, enables a fleeting contact (about



Clifford & Snell plug-in relay with fleeting contact.

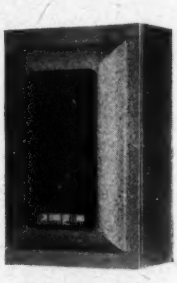
0·1 s) to be made or broken when the main relay is either energized or de-energized (or both). This arrangement has several advantages over the type fitted with a mercury switch of the quick-strike type, since it can be used in mobile applications, and is not restricted to normally open operation.

(D. Robinson and Co., Ltd., 5-7 Church Road, Richmond, Surrey.)

1163

Electronic Timer

Printed circuits and a cold cathode trigger tube are the salient features of a new electronic timer unit which can be used for single-shot



Richard Allan electronic timer.

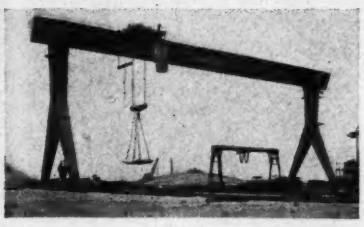
operation or for fast repetition with a recovery time of 40 ms. Three models are available, the first two having a single setting switch, with time ranges of 0·1-5 s and 1-55 s respectively. The third model (illustrated) has, in addition, five 50-s delay circuits which can be switched in as required, giving a total range of 1-305 s. All models are contained in dustproof aluminium cases, 7 in × 4½ in × 3½ in.

(Richard Allan Radio Ltd., P.O. Box 3, Taylor Street, Batley, Yorkshire.)

1164

Site Crane

Use of a triangular-section box girder as the main member is the outstanding feature of a crane installed to the order of Whessoe



Carruthers triangular-girder crane for Dungeness.

Ltd., at the Dungeness nuclear station now under construction, which will be used in the fabrication of the two pressure vessels.

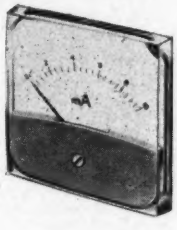
The crane has a span of 200 ft, a clear lift of 65 ft and a capacity of 40 tons. The use of the triangular section, in addition to its pleasing appearance, has resulted in savings in weight and manufacturing costs.

(J. H. Carruthers and Co., Ltd., East Kilbride, Glasgow.)

1165

Clear-front Instruments

Contemporary control panel design is catered for by a new range of Sangamo-Weston instruments with clear moulded covers of either



Sangamo-Weston clear-front instrument.

square or rectangular form, and cover inserts in a variety of colours (grey, blue, ivory, red, maroon, green, black).

Movements are moving-coil type with the well-known Weston spring-loaded jewels, and rectifiers for a.c. work, or thermocouples for h.f. work are incorporated.

(Sangamo Weston, Ltd., St. George's Court, 22-26 New Oxford Street, London, W.C.1.)

1166

Self-drilling Anchors

Main feature of the "Anchorfast" foundation bolt is that the expanding anchor unit into which the bolt screws, is provided with hardened teeth so that it forms

Anchorfast self-drilling expanding anchor.

its own masonry drill.

For flush anchorages, the anchor portion is provided with a necked shank which fits into a chuck to enable the hole to be drilled; after clearing the hole, the conical plug is inserted and the anchor driven home into the hole, after which the shank is broken off flush with the floor or wall surface. Other types of shank are available for fastening timber to concrete or for holding guy wires. The standard pattern is available in a range of sizes from $\frac{1}{4}$ in to $\frac{3}{4}$ in bolt diameter.

(Andrew Field and Co., Ltd., 17 Easton Street, High Wycombe, Bucks.)

1167

CONTINENTAL CATALOGUES

(Unless otherwise stated, all publications are in English or have English summaries.)

Leaflets received from **Gilardoni S.p.A.,** Mandello Lario (Como), Italy, describe the Gilatron 10 and Gilatron 45 mobile source units for industrial radiography and the Gilatron 3 000 and Cesagil 6 000 teletherapy units.

Switch and circuit-breaker units, metal clad switchgear and control cubicles are described in a general catalogue received from **SACE S.p.A.** Costruzioni Elettromeccaniche, 35 Via Baioni, Bergamo, Italy.

Demineralization (including boiler water treatment) by Asmit and Imac ion-exchange resins is described in a number of publications received from **Imact (Industrieele Maatschappij Activit N.V.),** P.O. Box 240-C, Amsterdam-N., Holland.

SAMES (Société Anonyme de Machines Electrostatiques), 21 Rue Jean-Mace, Grenoble, France, have sent us descriptive lists of particle accelerators, electrostatic generators and their "Uranie" water-moderated sub-critical assembly, using natural U and Po-Be or Ra-Be source. (British agents SAMES (Great Britain), Ltd., 44 Gorst Road, London, N.W.10.)

V.M.D.I. (le vide moleculaire dans l'industrie) vacuum equipment, including valves and cold traps, etc., is described in a leaflet (French) received from **S.A. Roger Grésillon,** 48 Rue Ramponneau, Paris 20.

La Physiotechnie, 34 Avenue Aristide-Briand, Arcueil (Seine), France, have issued a loose-leaf publication on the measurement and detection of ionizing radiation. Included are descriptions of the "Indilectra" quartz fibre dosimeters and chargers, the "Radiatest" audible and visible radiation monitor, and a quartz fibre dosimeter charger which operates by a built-in static generator, and does not require either battery or mains supply.

From **PHYWE Aktiengesellschaft,** Göttingen, come brochures of laboratory equipment for schools and for industrial laboratories, together with a booklet "Experiments in Atomic Physics."

"Hot Laboratory Tools for Safe Handling and Carrying" is the title of a leaflet issued by **P. Vogel et Cie.,** Veyrier, nr. Geneva. Pistol-grip handling devices and tongs are described, in addition to lead isotope containers with spherically seated swinging lids for easy and safe manipulation.

Descriptions of radiation-controlled level indicators for liquids, solids, or molten substances are given in descriptive literature received from **Forschungsanstalt für Strahlenmesstechnik Schaan,** Fürstentum, Liechtenstein. Leaflets (in German) also describe the "Rato" series of portable radiation alarms and monitors.

A brief summary of the range of plant manufactured for the nuclear industry, including charge/discharge machines, waste disposal installations tanks and pipework is given in a leaflet received from **F. J. Gattys,** 36 Vilbeler Strasse, Frankfurt am Main.

"Dürr" steam generating equipment of all types is described in a brochure received from **Dürrwerke Aktiengesellschaft,** Ratingen, W. Germany.

Some idea of the design and manufacturing resources available for the nuclear, chemical, oil and other heavy industries is given in a leaflet received from **SECEIM** (Société d'Etude de Constructions et d'Equipements Industriels Modernes), 27 Boulevard Berthier, Paris 17.

A reprint from *Atoomenergie* describing gas cooling equipment for Petten and equipment supplied for the CERN proton synchrotron, together with a list of other manufactures has been received from the **N.V. Brouwerk,** P.O. Box 28, Amersfoort, Holland.

"Introducing Nohab" is the title of a brochure, describing the development of the company from its foundation in 1847 to the manufacture of reactors 111 years later, issued by **Nydqvist & Holm Aktiebolag,** Trollhättan, Sweden.

"High Pressure Equipment" is the title of a leaflet issued by **W. C. 't Hart & Zn. Instrumenten en Apparatenfabriek N.V.,** 380 Adrianalaan, Rotterdam, which illustrates h.p. hydraulic ram pumps and pressure measurement equipment, autoclaves and gas compressors, together with high-pressure piping and C-ring seals for high temperatures.

Catalogues and leaflets received from **CFTH (Compagnie Française Thomson-Houston),** 173 Boulevard Haussmann, Paris 8, include:—"Metering and Monitoring Equipment for EL3" in both English and French and, in French only, similar information for the "Minerve" reactor at Fontenay-aux-Roses, in addition to publications on leak detection by mass spectrometer methods (in five languages) and general details of the Company's divisions and activities. (British agents, Leland Instruments Ltd., 145 Grosvenor Road, London, S.W.1.)

Publications (French only) from the **Fonderie de Gentilly S.A.,** 56 Rue Raymond-Lefevre, Gentilly (Seine), give particulars of all types of lead shielding, from a variety of standard bricks to a complete mobile foundry service for providing molten lead in bulk.

From **Siersatom,** 108 Avenue du Maine, Paris 14, comes a leaflet giving a brief survey of their range of nuclear manufactures, including glove-boxes, remote manipulators, lead shielding, decaning machines, diaphragm valves and chemical plant.

Brochures received from **W. C. Heraeus G.m.b.H.,** Hanau (London agents, Fleischmann (London), Ltd., Chancery House, Chancery Lane, London, W.C.2), describe electron-beam smelting of metals, high-vacuum plant and technology and high-frequency vacuum analysis. Most of these publications are in German only.

Amongst publications received from **ACEC (Ateliers de Constructions Electriques de Charleroi),** Charleroi, Belgium, are brochures on particle accelerators, nuclear instrumentation and general information on the origins and scope of the Company's activities. One of these is bilingual, in English and Russian.

Publications from **CSF (Compagnie generale de telegraphie Sans Fil),** 101 Boulevard Murat, Paris 16, describe the growth of the Group, and give general background information on the range of products and the activities of constituent companies.

Brochures (French only) from **Groupement Atomique Alsacienne Atlantique,** 100 Avenue Edouard Herriot, Le Plessis-Robinson, Seine, describe activities in the nuclear field, the principles of reactor control and flux measurement, ionization chambers, electromagnetic pumps, and the "Esquimau" sub-critical assembly for universities.

A brochure received from **CPIN (Companhia Portugesa de Industrias Nucleares)** lists the shareholding companies comprising the group and gives a brief survey (English and Portuguese) of their organization, industrial background and financial resources.

"Molybdenum" is the title of a 70-page brochure received from the **Metallwerk Plansee GmbH,** Reutte, Tirol (British agents, Elvants Ltd., Jubilee House, 114 High Street, London, N.W.10). The brochure deals with the production and properties of molybdenum, and lists the various forms in which the company supplies it. Other sections deal with applications and methods of working, and alloys.

From the Nuclear Power Department of **ASEA (Allmänna Svenska Elektriska Aktiebolaget)** of Västeras, Sweden, come two publications: a summary of nuclear products, including power and research reactors, and "Reactor Core Components." A wall chart, "ASEA Present the Atom," is another recent publication.

Continental Industries

Review of Nuclear Manufacturing Capacity Showing Nuclear Equipment Contracted or Supplied in Past Year

1. ADDRESS SECTION

AUSTRIA

AUSTRO-CHEMATOM KERNBRENNSTOFF GmbH, Linz/Donau, St. Peter 224. Tel.: 2.91.81. T.A.: Austro-Chematom Linzdonau 324.
Nuclear fuel production.
C 1.

ELIN-UNION AG, Vienna 1, Volksgartenstr. 3/5. Tel.: 44.96.41. T.A.: Elin Vienna. Telex: 01/1992.
Heavy electrical equipment.
Transformer with on-load tap changer for outdoor switch yard and complete power supply for Astra reactor, and experimental facilities at the Austrian Nuclear Research Centre, Seibersdorf, near Vienna (Oesterreichische Studiengesellschaft fur Atomenergie).

METALLWERK PLANSEE AG, Reutte, Tyrol. Tel.: Reutte 241. T.A.: Metallwerk Reutte.
Carbides and refractory metals for nuclear purposes; high density alloys for shielding against γ rays; nuclear grade metals.
Semi-finished products for U.K.AEA, CEA, Saclay, and CEN, Mol; research work for the Dragon Project in connection with uranium carbides, compatibility of metals with graphite.
J 3.

WAAGNER-BIRO AG, Vienna V, Margaretenstr. 70. Tel.: Vienna 57.95.45. T.A.: Vaagnerag Vienna. Telex: 01–1832.
Boilers, heat exchangers, pressure vessels, liquid and gas cleaning plants; fans, castings.
Heat exchanger for 5 MW research reactor, Astra for Studienges. f. Atomenergie, Vienna; 5 vacuum containers for the 25 GeV Synchrocyclotron, CERN, Geneva; 7 primary heat exchangers for high temperature gas cooled reactor, Dragon project; 6 secondary heat exchangers and a steam drum, 1 main shield plug also for the Dragon project.
D 1, 2, 3, 4; E 3, 4, 6, 7, 8, 9, 12; F 1, 2, 3, 4, 5, 6, 11, 14; H 1, 2, 3, 6; L 1, 13.

BELGIUM

ANBUMA, S. A., 147 rue de Breda, Antwerp. Tel.: Antwerp 31.18.10. T.A.: Anbuma. Telex: 03/468.
Wholesalers of pipes, tubes and valves, etc.
Globe, gate, check valves; piping, valves, fittings, etc., for Mol, Belgium.
E 6, 7, 8; F 3, 4, 5, 6.

APPLICOM S.A., 109 Avenue de France, Anvers. Tel.: 32.99.25. T.A.: Applicoma–Antwerp.
Agents for English Electric and other British companies.

SOCIETE D'ARENDONK, 29 Avenue Brugmann, Brussels 6. Tel.: 37.12.48. T.A.: Socarendo—Brussels.
Polythene tubing and sheeting.
Polythene tubing and sheeting, waste tanks for BR—2 and 3, C.E.N., Mol.
E 12; F 1; H 5, 7.

ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE CHARLEROI (A.C.E.C.), Avenue Rousseau, Marcinelle, Charleroi. Tel.: 07–36.00.20. T.A.: 07–27 Edempain—Charleroi.
Complete installations of nuclear power plant equipment.
Aluminium pressure vessel for nuclear reactor and emergency power supply for BR–2, Mol; electronic instrumentation and control equipment for reactor, control rod drive mechanisms for BR–2 and BRO–2, Mol, for C.E.N.; windings for the 2m hydrogen bubble chamber magnet for the proton-synchrotron, CERN, Geneva; special coil for power supply for the electron-synchrotron, DESY, Hamburg.
B 3; D 2, 4; E 3; F 5, 7, 8; G 1, 2, 6, 7, 9; H 1, 7; M 1, 3, 4, 10, 11; N 1, 2, 3, 4, 5, 6, 7, 8.

BELCHIM, 35 rue des Colonies, Brussels 1. Tel.: 13.60.90. T.A.: Nucleochim —Brussels.
Designing and building nuclear chemical plants, hot labs., fuel reprocessing plants, treatment of radioactive waste, disposal of radioactive effluents.
Designing and building of solvent-extraction pilot unit (in operation as from June, 1960) at Mol, for Eurochemic; designing as industrial architect part of the large scale plant to be erected at Mol including treatment and storage of liquid waste, purifying and decontaminating the water of the unloading, storage and mechanical handling pools, treatment of radioactive residues from the decontamination room and other parts of the plant; final purification of uranium, at Mol, for Eurochemic.
E 8, 9; H 3, 4, 5, 6, 7; J 1, 4; L 1, 2, 3, 4, 5, 6, 7, 12, 13.

SOCIETE BELGE POUR L'INDUSTRIE NUCLEAIRE, S.A., "BELGO-NUCLEAIRE," 35 rue des Colonies, Brussels 1. Tel.: 13.60.90. T.A.: Nucleus—Brussels.
Reactor engineering and construction, plutonium cycle technology, radioisotopes.
Complete reactor and irradiation facilities for Siloe research reactor, Institut Interuniversitaire des Sciences Nucléaires, Ghent; plutonium laboratory equipment for Mol, for Euratom; γ ray sources and detectors to control the load elevation in blast furnaces for Rama control, Italsider, Italy.
A 1; B 2, 4; D 1, 2, 3, 4; E 3, 4, 5, 8, 9; F 1, 2, 3, 4, 6, 7, 12, 13, 14; G 1, 2, 6, 7, 9; H 1, 2, 3; J 3; K 14, 16; L 1, 2; M 1, 2, 3, 5, 6, 8, 10, 11; N 1, 2, 3, 4, 5, 6, 7, 8, 10; P 1, 2, 3.

BELL TELEPHONE MFG. CO., Francis Wellesplein 1, Antwerp. Tel.: 37.78.00. T.A.: Microphone—Antwerp.
Electronic instrumentation.
Complete control and instrumentation for Siloe I swimming pool reactor for the University of Ghent.
M 6, 7, 10; N 1, 2, 4, 7; P 2.

BUREAU D'ETUDES NUCLEAIRES (B.E.N.) S.A., 47 Rue Montoyer, Brussels. Tel.: 13.38.20. T.A.: Belgatome.
Architect and consulting engineers.
Architect and consulting engineers for the study of the nuclear part of the installations and the supervision of erection (in association with SOFINA) for BR 2, Mol, CEN; the same (in association with Société de Traction et d'Eléctricité and BelgoNucléaire) for BR 3, Mol, CEN; architect and consulting engineers for the nuclear part of the installation (in association with ECETRA, Electrobel, SOFINA, Société de Traction et d'Eléctricité, engineering groups of EDF) for 242 MW(e) nuclear power plant to be built at Chooz (Givet), Centrale Nucléaire des Ardennes, Société d'Energie Nucléaire Franco-Belge des Ardennes (SENA).

S. A. CARNOY-VANDENSTEEN, 56 Bd. du Petit Dock, Gand-Gl.ent. Tel.: 09/23.24.81. T.A.: Carnoy-Vandensteen-Gand.
Pipework.
Auxiliary and waste piping in carbon and stainless steel and aluminium for BR 3 power plant, Mol, for C.E.N.; waste piping and instrumentation for BR 2, Mol.
F 1, 2, 3.

COMPAGNIE BELGE DE CHEMINS DE FER ET D'ENTREPRISES S.A., 33 rue de l'Industrie, Brussels 4. Tel.: 12.51.50. T.A.: Secondaire—Brussels.
Civil engineering.
Civil engineering in conjunction with Auxeltra-Génie Civil for reactors at Mol.

COCKERILL-OUGREE S.A., Avenue Greiner 1, Seraing. Tel.: Liège 34.08.10. T.A.: Cockerill-Ougrée-Seraing.
Pressure vessels, steam generators, main coolant piping, containment vessels.
Containment vessels for BR 2 and 3, Mol; erection work of main reactor equipment for BR 3, Mol, C.E.N.
D 1, 2, 3; E 4, 6, 8, 9; F 1, 2, 3, 5, 14; H 2; K 14.

SOCIETE D'ETUDE ET DE CONSTRUCTION EVENCE COPPEE, 103 Boulevard de Waterloo, Brussels 1. Tel.: 38.60.30. T.A.: Evence Coppée —Brussels. Telex: 02.139.
Architect/engineers.
Active waste incinerator for Mol, C.E.N.; swimming pool reactor water cooling, design of reactor building and auxiliaries for the University of Ghent, for BelgoNucléaire.

SOCIETE EVENCE COPPEE ET CIE, 103 Boulevard de Waterloo, Brussels 1.
An industrial holding company associated with Société d'Etude et de Construction Evence Coppée. In the nuclear field the company participated in the foundation of nuclear companies such as Belchim and Belgo-Nucléaire.

S.A. USINES EMILE HENRICOT, Court-Saint Etienne. Tel.: 010/62.20.5. T.A.: Henricot—Court-St. Etienne.
Steel castings in ordinary and special steels; forged and rolled special steels (bars and sheets); centrifugal pipes in special steels.
Indirect supplies to C.E.N., Mol, and French atomic centres.
K 14.

SOCIETE GENERALE METALLURGIQUE DE HOBOKEN, 14 rue Greiner, Hoboken, Antwerp. Tel.: 38.58.80. T.A.: Metaux—Antwerp. Telex: 03/443 Hometaux Antw.
Treatment of uranium concentrates.
Nuclear grade uranium products for the manufacture of fuel elements—Oxides—UO_2 (standard and ceramic grades), UO_3 and U_3O_8; metal direct and vacuum remelted ingots; salts. Sole agents: Societe Generale des Minerais, 31 rue du Marais, Brussels.
J 1, 2, 3.

MANUFACTURE BELGE DE LAMPES ET DE MATERIEL ELECTRONIQUE (M.B.L.E.), S.A., 80 rue des Deux-Gares, Brussels 7. Tel.: 02/21.82.00. T.A.: Mazda Brussels. Telex: 02/420.
Electronic instrumentation.
Complete nuclear reactor health monitoring equipment for Mol, C.E.N.; low background measurement equipment for Grenoble, C.E.A.; coincidence measurement equipment for Euratom nuclear research centre, Ispra, Italy; nuclear measurement installations for many laboratories in European and other countries.
G 4; M 10; N 1, 2, 7.

METALLURGIE ET MECANIQUE NUCLEAIRES, 33-39 rue Voie de Liege, Herstal-Lez-Liege. Tel.: 64.08.00. T.A.: Numetal—Herstal. Telex: Liege 223.
Fuel elements, complete cores, precision engineering.
Prototype fuel elements for BR-2, silver plating of heavy bolts (pressure vessel) for BR 3, for C.E.N.—Babcock—Smulders; neutron chopper channel for neutron source for Euratom; metallic uranium fuel elements, uranium alloys, zircalloy tubing for Eurochemic, Mol; metallic uranium fuel elements, aluminium vessel for BelgoNucléaire; metallic uranium bars for CAMEN, Italy, and metallic uranium plates for Italatom, Italy.
C 1, 2, 3.

Belgium (contd.)

COMPAGNIE DES METAUX D'OVERPELT-LOMMEL ET DE CORPHALIE S.A., 54 rue de Fabriques, Brussels 1. Tel.: 12.31.30. T.A.: Overcor Brussels.
Shielding bricks and shielding panels.
L 3.

SOCIETE DES MINES ET FONDERIES DE ZINC DE LA VIEILLE-MONTAGNE, S.A., Angleur. Tel.: Liège 65.38.00. T.A.: Vieilmont—Angleur. Telex: Liège 256.
Lead bricks, containers and sheets. Zinc bromide.
K 15; L 3, 4.

ETABLISSEMENTS NEU S.A., 190 Chaussee de Bruxelles, Tournai. Tel.: 210.61. T.A.: Etneu—Tournai.
Air conditioning, pneumatic conveyors, dust removal, fans and blowers.
Movable air cleaner for radioactive rooms for Métallurgie et Mecanique Nucléaires, Herstal; enlargement of ventilating and air conditioning plants for BR 2 and 3 at Mol, C.E.N.; also air conditioning and ventilation from laboratories.
F 11; H 3, 4.

S.A. DES NOUVEAUX ATELIERS LEBRUN, Nimy. Tel.: 065/37641. T.A.: Lebrun Nimy. Telex: 065.42.
Heat exchangers, compressors, refrigeration, air conditioning.
13 beam ports and accessories (complete installation), 13 stainless steel castings, total weight 70 tons for BR 2 (materials testing reactor) at Mol, CEN.
E 9; F 1, 2, 3, 14; H 1; M 11.

PHENIX WORKS S.A., Flemalle-Haute, Liege. Tel.: 33.78.19. T.A.: Borgal Liège.
Cladding steel or aluminium plates with pvc.
Decontaminable ventilation ducts; walls; ceilings and partition walls for various types of rooms; lining of laboratory tables and benches; measuring equipment boxes; drums in ordinary steel, protected on one or on both faces by a film of pvc.
L 10, 13.

SERAI, 1091 Chaussee d'Alsemberg, Brussels 19. Tel.: 44.19.15. T.A.: Setreda Brussels.
Research and development, precision mechanisms, instrumentation, specialist physical and chemical investigations.
Confidential research.
M 8, 9.

S.A. SOBELCO, 58 rue Capouillet, Brussels 6. Tel.: 37.12.90. T.A.: Sobelco Brussels.
A condensation and reheating plant for a Westinghouse turbine for BR 3, Mol, CEN; equipment for radiation level measurement in the secondary circuit, BR 3, Mol; purification of the radioactive demineralization effluent, test reactor, Ghent, BelgoNucléaire.

DENMARK

A/S BURMEISTER AND WAIN'S MASKIN-og SKIBSBYGGERI, Strandgade 4, Copenhagen K. Tel.: Asta 250. T.A.: Burmeisters Copenhagen. Telex: 2366.
Heavy plate fabrication, piping, etc.
E 3.

ELSINORE SHIPBUILDING AND ENGINEERING CO., LTD., Elsinore. Tel.: 21.14.00.
Boiler manufacture, general fabrication.
Compressor for distillation plant for contaminated water from DR 3; turbine driven helium circulator for O.E.E.C. Dragon Project. Both supplied to A.E.K., Risø.
F 11; L 13.

A/S HASLE KLINKER-og CHAMOTTESTENSFABRIK, Osterbrogade 6, Copenhagen O. Tel.: TRia 6201. T.A.: Hasleklinker.
Manufacture of refined ceramic building materials.
E 13.

THOMAS B. THRIGE, Tolderlundsvej, Odense. Tel.: Odense 11.13.15. T.A.: Thrige Odense.
Electrical machinery.
Seven motor generator sets for CERN, Geneva; 7 coils for β ray spectrometer for U.S.A. On order: 1 spent fuel element storage magazine for Dragon Project; 2 quadrapole lenses for the Institute of Technische Kernphysik, Darmstadt.
H 1; M 1, 11.

A/S FRICHS, Aarhus. Tel.: 061/58.55.5. T.A.: Frichs Aarhus.
General fabrication, machining, casting, stand-by generators.
Load/unload flask, mechanical parts for the vertical and horizontal flasks, for DR-3, Risø, Danish Atomic Energy Commission.
L 13.

FRANCE

SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES (SACM), 69 rue de Monceau, Paris 8e. Tel.: Lab 60-50. T.A.: Alsatelec.
Control equipment, electronic instrumentation.
Nuclear equipment contracted through daughter company GAAA; study of fabrication of ionization chambers of various types, with associated electronic equipment; study and construction of a burst slug detector suitable for a water cooled reactor; study and construction of remote control and safety equipment for test sodium circuits at Cadarache; general studies of charge/discharge systems for graphite/gas reactors; study and construction of a monitoring 260 channel measurement centre; study of automation and centralized control of the main charge equipment for EDF3.
G 1, 2, 3, 5, 9; M 5, 6.

SOCIETE ALSTHOM, 38 Avenue Kleber, Paris 16e. Tel.: PAS 71-19. T.A.: Alsthom Paris.
Power plant engineering.
Turbo-alternators for EDF 1 and 2, at Chinon, EDF; Rapsodie design study at Cadarache for CEA; studies, special motors and frequency converters for Pierrelatte, USSI; exchangers for Villeras, SRTI.
B 1, 3, 4; E 4, 12; F 14; G 9; M 1, 9, 11.

ANALAC, SOCIETE POUR L'ETUDE ET LA REALISATION DES PROCEDES ELECTRONIQUES DE CALCUL. 101 Bd. Murat, Paris 16e. Tel.: AUTeuil 81.25. T.A.: Calana Paris.
General purpose or specialized analogue computers.
M 5.

ETABLISSEMENTS BEAUDOUIN, 1 and 3 rue Rataud, Paris 5e. Tel.: POR 49-19. T.A.: Scientifap Paris TT.
Vacuum pumps, micromanipulators, electromanipulators, spectrographs, X-ray crystallography apparatus, ionization chambers.
Vacuum pumps: blade type, 3·5m³/h and 10m³/h; oil diffusion type, 65 l/sec and 300 l/sec; ionization chambers, electro-magnets, monochromator in vacuum, for CEA.
N 5, 8.

ETABLISSEMENTS J. BODSON ET FILS, 14 bis, rue Denis Papin, Puteaux (Seine). Tel.: LONgchamp 09-37.
Endoscopes and periscopes.
Endoscopes and periscopes for Saclay, Marcoule, Grenoble and Fontenay-aux-Roses nuclear centres.
L 11; N 1.

BONNET-CALAD S.A., Bd. Pierre Pasquier, Villefranche S/Saone, Rhone. Tel.: 15.70. T.A.: Bonnet-Calad Villefranche S/Saone.
Mixers specially adapted to nuclear problems (preparation of nuclear fuels, neutralization of residuary deposits, etc.).
Superlabo No. 1, type M.8 for Cadarache, CEN; Cyclorex A.56 for Marcoule, CEA; Superlabo M.8 and Cyclorex C.100, D.150, A.56 for Saclay, CEN; Cyclorex A.56 for Le Bouchet, CEA; Supermélangeur M.95 for Vaujours, CEA.
M 11.

BREVATOME, 25 rue de Ponthieu, Paris 8e. Tel.: BALzac 17-80. T.A.: Brevatome Paris.
Management and filing of patents, documentation.

CENTRE D'ETUDES ET DE REALISATIONS ELECTRONIQUES (CERE), 79 Bd. Haussmann, Paris 8e. Tel.: ANJ 84-60. T.A.: Tesafi Paris.
Electronic instrumentation, monitoring systems, G-M counters.
Survey and contamination meters.
N 1, 2, 3, 4.

CIE INDUSTRIELLE DES COMBUSTIBLES ATOMIQUES FRITTES (CICAF), Domaine de Corbeville par Orsay (S. and O.). Tel.: 928/53.35. T.A.: Cicaf—Corbeville par Orsay.
Research into and fabrication of ceramic fuel elements.
UO_2 fuel elements for critical experiments at Saclay, CEA; UO_2 fuel elements for critical experiments, AEC of Denmark.
C 1, 3; G 1.

COMMISSION DE L'INSTRUMENTATION NUCLEAIRE FRANCAISE, 23 rue de Lubeck, Paris 16e. Tel.: PAS 01-16.
Electronic instrumentation.
Various equipment and apparatus for laboratories and research for CEA IAEA, International Centres of Euratom, ENEA and for French and foreign laboratories and universities.
G 1, 2, 3, 4, 5, 6, 7, 8, 9; M 1, 4, 5, 6, 7, 10, 11; N 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; P 2.

COMPAGNIE DES ATELIERS ET FORGES DE LA LOIRE (CAFL), 12 rue de la Rochefoucauld, Paris 9e. Tel.: TRInite 81-50. T.A.: Forgaloire Paris.
Stainless, heat-resisting and all alloy steels.
General engineering construction, apparatus for the handling of nuclear fuels, ballast plates for EDF 1, Chinon, EDF; reactor handling apparatus, accelerator components for EDF 2, Chinon, EDF; CEA, Saclay; and CERN.
D 1, 2, 3, 4; E 2, 4, 7, 9, 12; F 1, 2, 3, 14; G 6, 7; H 1, 2; J 1, 4; K 14; M 1.

COMPAGNIE CENTRALE D'ETUDES INDUSTRIELLES "COCEI", 127 Rue de Saussure, Paris 17e. Tel.: Mac 56-90.
Electrical engineering.
General control and burst fuel element detection for Chinon nuclear power plant, EDF 2, EDF, and for a gaseous diffusion plant for CEA; control and electrical engineering for the experimental reactor, Pégase, CEA.
G 5.

C.S.F. (COMPAGNIE GENERALE DE TELEGRAPHIE SANS FIL), 79 Bd. Haussmann, Paris 8e. Tel.: ANJou 84-60. T.A.: Tesafi Paris. Telex: 20.936.
Nuclear instrumentation, control, regulation, reactor data treatment; computers, simulators; particle accelerators, mass spectrometers, ion sources, particle separators, special materials.
1 000 MeV linear electron accelerators for Laboratoires de Hautes Energies, Ecole Normale Supérieure, Faculty of Science, Orsay; production of sintered nuclear fuels for Saclay nuclear reactors, CEA; automatic control of nuclear centres for French electricity supply, two nuclear stations at Chinon, EDF; particle separators and sundry nuclear instrumentation for nuclear research centres, CEA; radiation detectors (CERE) for nuclear centres, CEA, civil protection centres, Ministry of the Interior, and Reganne Centre, Ministry of National Defence; mass spectrometer SM 501 for an isotope separation plant, CEA; mass spectrometer SM 500 for nuclear centres in Yugoslavia; water-tight electrically driven pumps for primary reactor circuits for EL 2 and 3 piles, CEA, and for Dido reactors, Denmark; special investigations (materials, thermo-nuclear fusion, engineering) for miscellaneous nuclear laboratories of CEA and Euratom.
C 3, 4, 7; D 5; F 7, 8; G 1, 4, 6, 7, 9; J 3; K 5; L 3; M 1, 2, 5, 6, 7, 10, 11; N 1, 2, 3, 4, 5, 7, 9, 10; P 2.

COMPAGNIE EUROPEENNE D'AUTOMATISME ELECTRONIQUE, 27 rue de Marignan, Paris 8e. Tel.: ELYsées 47-97. T.A.: Autelec Paris.
Digital control computers, data loggers.
Burst slug detection system with 2 RW 300 computers for EDF 2 nuclear power plant; data reduction system with an RW 530 computer for model of Rapsodie for CEA.
M 5, 6, 7.

CONSTRUCTIONS RADIOELECTRIQUES ET ELECTRONIQUES DU CENTRE (C.R.C.), 19 Rue Daguerre, St.-Etienne. Tel.: 39-77. T.A.: Circe St.-Etienne.
Electronic instrumentation.
Radioactive particle detectors, fixed and monitor for CEA.
N 1, 2, 10.

DEGREMONT (S.A.), 183 route de Saint-Cloud, Rueil-Malmaison (S. and O.), B.P. 46 a Suresnes (Seine). Tel.: LONgchamp 66.50. T.A.: Aquazur Suresnes.
Water treatment. Concentration and recovery of uranium by ion exchange.
Filtration and demineralization of water from fuel element decanning and storage pools, at Marcoule; uranium recovery and decontamination plant for Saclay; treatment of core water of Peggy; water treatment plants at Pierrelatte and Cadarache; demineralization plant and general supply and cooling pond treatment at Fontenay-aux-Roses.
H 4, 5, 6; J 1, 4.

France (contd.)

FORGES ET CHANTIERS DE LA MEDITERRANEE, 6-8 rue Camou, Paris 7e. Tel.: Sol 99-99. T.A.: Vasco.
Heavy plate fabrication, mechanical devices, general piping, special copper alloy (Mangal).
Steel and other metal parts (various vessels and tanks, piping, mechanical devices), for Ulysse, CEA, and absorber rod drives for Dragon, ENEA.
G 7.

SOCIETE DES FORGES ET ATELIERS DU CREUSOT (USINES SCHNEIDER) (SFAC), 15 rue Pasquier, Paris 8e. Tel.: ANJou 34-40. T.A.: Forgeac Paris. Telex: Monetoy 27.776.
Carbon, alloy and stainless steels, mechanical plant, structural steelwork, heavy plate work.
Carbon dioxide main pipework for EDF 2, EDF; refuelling machinery for EDF 1 and 3, EDF; machined graphite stacking for EDF 1 and 2, EDF; simulating reactor Rapsodie, including stainless steel vessel, with its inner supporting base, intake and outlet sodium pipework, mechanized plugs with their remote controls, at Cadarache Nuclear Centre, CEA.
D 1, 2, 3, 7; E 4, 9; F 1, 2, 3, 12; G 7; H 1; K 14; M 1, 11.

L'ELECTRONIQUE APPLIQUEE, 25 rue du Docteur Finlay, Paris 15e. Tel.: ALEsia 45-20. T.A.: Lelapli.
Nuclear instrumentation reactor control equipment (Burst fuel element detection).
Burst fuel element detection equipment for G 3, Marcoule, CEA; filtration unit control for G 2 and 3, Marcoule, CEA; also for EDF 1, Chinon, EDF; basic electronic instrumentation (assemblies of standard functional units) for Saclay and Marcoule, CEA, Chinon and Grenoble EDF, Geel and Ispra, Euratom, Vienna, IAEA; Geneva, CERN, and for Vinca, Yugoslavia.
G 5; H 4; M 4, 8, 10; N 1, 2, 3, 7, 10; P 2.

FRANCE-BARYTES, 26 Rue Jullien, Marseilles (3e). Tel.: 62.38.00. T.A.: Carbacti Marseilles. Telex: 41.958 Ceca Marsl.
Barytes for nuclear concrete.
1 000 tons of barium sulphate for concrete shielding for CERN.

GAMMA INDUSTRIE S.A.R.L., 52 Rue de Dunkerque, Paris 9e. Tel.: TRUdaine 83-82. T.A.: Wellward Paris.
Gamma radiographic equipment and services, electromagnetic isotope separator.
Gamma radiographic equipment: 2 000 curies, cobalt 60 for EDF; electromagnetic separator for the Nuclear Research Institute, Strasbourg University.
L 6; M 1; N 8; P 2.

GENERALE THERMIQUE, 9 rue Marceau, Le Pre Saint Gervais (Seine). Tel.: VIL 89-92. T.A.: Genethermique Paris.
Heat exchangers, steam generators.
Heat exchanger, steam generators for Cadarache Centre.
F 14.

GROUPEMENT ATOMIQUE ALSACIENNE ATLANTIQUE (G.A.A.A.), 100 avenue Edouard Herriot, Le Plessis Robinson (Seine). Tel.: ROB 53-44.
Reactor design, engineering, construction and equipment.
Architect engineer of the breeder Rapsodie, design and manufacture of sodium loops preliminary to Rapsodie, and their control; design and manufacture of a model for safety tests of Rapsodie; design study of a test loop for thermal shocks and of the cutting shop of the fuel element assemblies for Rapsodie; general design study of Rapsodie charge/discharge equipment and of the control system; measurement of the neutron power in EDF 2; computation and nuclear study of the EDF 3 containment; design study of the main charge/discharge equipment of EDF 3; design and construction of several irradiated element laboratories (uranium and plutonium); general study of the safety and protection of nuclear reactors; preliminary design of the test reactor Essor (ORGEL programme), all for CEA.
B 1, 2, 5; E 4; F 1, 2, 3, 6, 9, 10, 14; G 1, 2, 3, 5, 6, 7, 8, 9; L 1, 7, 8, 12, 13; M 3, 5, 6, 8, 11; N 1, 2, 5.

INDATOM, 48 rue la Boetie, Paris 8e. Tel.: BAL 83-40. T.A.: Indatom Paris.
Architect/engineers.
Design and construction, as industrial architect, of the nuclear research reactor (swimming pool) Siloé, Grenoble; design and construction of the heavy water nuclear power plant (80 MW) EL-4, Brennilis; design and construction of the EDF 2 power plant fuelling machine, Chinon, all for CEA; design of the project Essor before the realization of ORGEL (organic moderated gas cooled reactor, ORGEL, Ispra, for Euratom).
A 1, 2; B 1, 2, 3, 4, 5.

INTERTECHNIQUE, 81 rue Escudier, Boulogne (Seine). Tel.: MOLitor 83-20. T.A.: Intertec Boulogne.
Electronic instrumentation.
Burst slug detection equipment (detectors and data processing) for EDF 1, EDF.
G 5.

JEUMONT (FORGES ET ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE JEUMONT), 5 Place de Rio-de-Janeiro, Paris 8e. Tel.: CARnot 08-60. T.A.: Jeumontelec Paris.
Heavy electrical equipment.
Several high-power electromagnets and motor-generator sets, remote control and signalling apparatus for gas valves for high energy research laboratory and reactors, CEA, Saclay, and EDF, Chinon.
M 10, 11.

ETABLISSEMENTS KUHLMANN, 25 Bd. de l'Amiral Bruix, Paris 16e. Tel.: KLEber 50-50. Telex: Etakuhlm Paris 27.640.
Chemical processing of uranium ores, ultra pure metal production.
Hydraulic circuits and control engineering for Pegase, uranium processing plant, CMUF, CEA.
J 1, 3; K 6, 13.

COMPAGNIE LYONNAISE DE GENIE CHIMIQUE P. LACOLLONGE, 50-54 cours de la Republique, Villeurbanne (Rhone). Tel.: Villeurbanne 84-83-68. T.A.: Ebonitage Lyon.
Abrasion and corrosion protection.
Work carried out at Getigne, Bessine, and St.-Priest-La-Prugne, SIMO, Gueugnon, Narbonne Malvésie and Mounana (Gabon), CEA; Mol, Elgique, and Geneva, CERN.
E 12.

SOCIETE LORRAINE-ESCAUT, 7 Rond-Point Bugeaud, Paris 16e. Tel.: PAS 35-39. T.A.: Lorenesco Paris.
Heavy and medium steel plates, cables for prestressed concrete, steel and stainless steel welded and seamless tubes and canning.
Heavy and medium plates for pressure vessel of EDF 1, Chinon, for Cie Française d'Entreprises; pipework and strakes for 120 heat exchangers for EDF 1, Chinon, for Cie des Surchauffeurs; pipework for 96 heat exchangers for EDF 2, Chinon for Cie des Surchauffeurs; pipework for EDF 1 for Ets. Levivier; burst slug detection tubes for EDF 1 and 2 for COMSIP; treated wire for prestressed concrete for G 2 and 3, Marcoule, for Cie Industrielle de Travaux.
C 5; D 1, 3; E 2, 4, 7, 8; F 1, 2, 3, 14; G 5, 6, 7; K 14.

ETS. MERLIN ET GERIN, rue Henri Tarze, Grenoble, Isere. Tel.: 44.56.30. T.A.: Merger Grenoble.
Electric apparatus, electronic instrumentation.
G 4; N 5.

METALLURGIE FRANCAISE DES POUDRES "METAFRAM," 56 rue de Londres, Paris 8e. Tel.: EURope 26-70. T.A.: Metaframem.
Powder metallurgy, mechanical parts, self-lubricating bearings, filters, friction elements.
Filters, bearings for bubble chambers; filters for Rapsodie, CEA; control rods for EDF 1 and 2, CEA.
G 6; H 4.

SOCIETE ANONYME DES ETS. NEU, 47 rue Fourier, Lille (Nord). Tel.: 57-10-56. T.A.: Etneu Lille.
Air conditioning, pneumatic conveyors, dust removing, fans and blowers.
Fans and blowers, "Grisbi" room air cleaner for radioactive laboratories, including an absolute filter for CEA; dust removal from one discharging unit, CEA, Narbonne; ventilating from rooms for radioactive waste packing, CEA, Saclay; ventilating several rooms, CEA, Gueugnon; dust removal from workroom, ventilating from stocking room, CEA, Le Bouchet; ventilating and air conditioning from a purifying room, CEA, Marcoule; air conditioning from leader laboratories and ventilating from several workrooms, CEA, Pierrelatte.
F 12; H 3, 4.

OERLIKON S.A., 15 rue de Milan, Paris 9e. Tel.: TRInite 28.61. T.A.: Oerlik Paris.

OPTIQUE ET PRECISION DE LEVALLOIS, 106 rue Chaptal a Levallois (Seine). Tel.: PER 79-40. T.A.: Precioptic Levallois.
Optical-mechanical instrumentation.
Telemicroscope for CEA, Saclay.
M 10.

PECHINEY, 23 rue Balzac, Paris 8e. Tel.: CAR 54.72. T.A.: Péchiney Paris. Telex: 20.047.
Production of graphite (rough and machined), beryllium, beryllium oxide, zirconium, thorium, thorium oxide, uranium oxide and carbide (rough, sintered and machined), rare earths.
100 tons machined graphite blocks to Atomic Energy Installation Trombay (India); 1 aluminium clad complete graphite reflector Belgo-Nucléaire; 1 thermal column (graphite), Petten reactor, Reactor Centrum Nederland; 1 moderator and reflector complete (3 000 t machined bars), EDF 2, EDF; 10 tons beryllium flake, U.K.AEA; 4 000 pounds beryllium oxide, Curtiss Wright; 300 kg thorium oxide, Euratom.
A 6; B 1; D 5, 6, 7; J 3; K 1, 2, 3, 5, 6, 7, 8, 9.

S.A. PERMALI, 22 rue La Fayette, Maxeville-Nancy (M. and M.). Tel.: Nancy 52.08.55. T.A.: Permali Nancy.
Industrial laminates with wood and synthetic resin base.
High hydrogen content biological shields with high mechanical resistance, complex shields with high boron and hydrogen content, special shields used in large assemblies (atomic pile charge faces, fuel charge machines, etc.).

LA PHYSIOTECHNIE, 34 Av. Aristide Briand, Arcueil (Seine). Tel.: PELletan 16-10. T.A.: Diady Arcueil.
Dosimeters, apparatus for detecting and measuring x-rays and gamma-rays, ion chambers.
N 4, 5.

S.A. DES ACIERIES DE POMPEY, 61 rue de Monceau, Paris 8e. Tel.: LABorde 97-10. T.A.: Pompeac Paris. Telex: Pompeac Paris 27.826.
Fine and special steels (corrosion resisting, stainless, etc.).

QUARTZ ET SILICE, 8 rue d'Anjou, Paris 8e. Tel.: ANJou 17.36. T.A.: Siliquartz 123 Paris. Telex: 27078 Silis Paris.
All organic and inorganic phosphors.
N 6.

LA RADIOTECHNIQUE, 130 Avenue Ledru Rollin, Paris 11e. Tel.: Voltaire 18-50. T.A.: Tubelec Paris.
Electronic tubes and semiconductors.
Photomultiplier tubes, scintillators, fission chambers, semiconductor detector devices, to CEA.
G 3; N 4, 5, 6.

SOCIETE RATEAU, 141 rue Rateau, La Courneuve (Seine). Tel.: FLAndre 18-80. T.A.: Turmachi Lacourneuve.
General fabrication.
5 experimental loops for fuel element thermal testing, special tight blowers for test loops at Saclay Centre, for CEA; 8 gas-bearing blowers for Pegase reactor, Cadarache, for CEA.
B 4; E 9; F 5, 6, 7, 8, 9, 10, 11, 12; G 5; H 3; M 8, 9, 11.

ENTREPRISE RAZEL FRERES, 17 rue de Tolbiac, Paris 13e. Tel.: PORt-Royal 45-59. T.A.: Razelfrer Paris.
Civil engineering.
Earthworks and foundations at Chinon Nuclear Centre, for EDF; also for the Pierrelatte installation for USSI, Centrale de Séparation d'Isotopiques, CEA.

SNECMA, 22 Quai Gallieni, Suresnes (Seine). Tel.: LONchamp 28-70.
Aircraft engines.
Blowers at Chinon, EDF 1, for EDF. Preliminary design study for Pegase at Cadarache for CEA.
C 5, 6; F 10, 14, 15; M 8, 10, 11; N 8, 10.

SAINT-GOBAIN NUCLEAIRE, 23 Boulevard Georges Clemenceau, Courbevoie (Seine). Tel.: MERmoz 10-00. T.A.: Atogobain Neuilly.
Designs, installations and equipment for the nuclear industry, reprocessing, hot laboratories.
Chemical reprocessing plant, decanning plant, installation for the storage of fission products, hot cells at Marcoule, for CEA; storage pool and mechanical decanning plant, chemical reprocessing plant, installation for the storage of fission products, plant for effluent treatment at La Hague, for CEA; pyrometallurgical cell at Grenoble, for CEA; installation for the treatment of wastes from Rapsodie, installation for pyrometallurgy at Cadarache, for CEA; laboratory hot cells at Saclay, for CEA; effluent treatment and waste disposal plant, hot cells at Chinon, for EDF; hot cells at Karlsruhe for KBB; hot cells at Karlsruhe and Ispra for Euratom; hot cells and chemical reprocessing plant at Mol for Euratom and Eurochemic; special instruments for observation and remote handling in hot laboratories.
H 3, 4, 6, 7; J 2, 3, 4; L 1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13; P 3.

SAMES, SOCIETE ANONYME DE MACHINES ELECTROSTATIQUES, 21 rue Jean Mace, Grenoble, Isere. Tel.: Grenoble 44.77.64. T.A.: Electrostatic Grenoble. Telex: 31.814.
High voltage electrostatic generators, particle accelerators and neutron generators, "Uranie" sub-critical reactor.
Accelerators and generators have been supplied to Saclay, Fontenay-aux-Roses, France; Harwell, Windscale, Aldermaston, Great Britain; Cern, Switzerland; Brookhaven, U.S.A.
M 1, 2, 3.

France (contd.)

SOCIETE D'ETUDES DE CONSTRUCTIONS ET D'EQUIPEMENTS, INDUSTRIELS MODERNES, 27 Boulevard Berthier, Paris 17e. Tel.: GALvani 80–59.
Architect/engineers.
Design and construction of instruments for nuclear physics research, apparatus for high vacuum and low temperatures, hot laboratories specializing in research, technology, preparation of fuel elements, at Saclay, Fontenay-aux-Roses and Cadarache, for CEA.
M 10, 11.

SFIM (SOCIETE DE FABRICATION D'INSTRUMENTS DE MESURE), Avenue Marcel Ramolfo Garnier, Massy (S. and O.). Tel.: 928.10.90. T.A.: SFIM Massy.
Instrumentation and control.
Pressure transducer for hexafluoride/uranium plant for CEA.
G 4; N 3.

SOCIETE INDUSTRIELLE DE COMBUSTIBLE NUCLEAIRE, 69 rue de Monceau, Paris 8e. Tel.: LAB 60–50.
Fuel elements.
Fuel elements for G 1, G 2, G 3 and EDF 1; contract for the outer fertile elements of the breeder Rapsodie; design contracts for the fuel elements of EDF 2 and EDF 3, for CEA.
C 1.

SOCIETE L'ELECTRO-ENTREPRISE, 32 rue de Mogador, Paris 9e. Tel.: PIGalle 67–02. T.A.: Electrise Paris.
Electrical installations—control and monitoring panels, cabling.
Study of electro-technical assemblies, supply and fitting of remote control panels, power, control and indication cabling, automatic burst slug detection equipment for EDF 1 nuclear centre, Chinon, EDF; supply and fitting of remote control panels, power, control and indication cabling, automatic burst slug detection equipment, for EDF 2, Chinon, EDF.
G 9.

SOCIETE D'ELECTROCHIMIE, D'ELECTROMETALLURGIE ET DES ACIERIES ELECTRIQUES D'UGINE, 10 rue du General Foy, Paris 8e. Tel.: Europe 31–00. T.A.: Trochim Paris.
Special materials.
UF_6 production, zirconium, special nuclear steels, aluminium-magnesium, sodium-cobalt, sintered metals filters, magnets, measurement apparatus, glove-boxes, fluorinated products, fluorinated resins, chlorinated and oxygenated products, for CEA.
A 6; B 1, 5; D 1, 3, 4, 5, 7; E 8; F 3; H 4; J 3; K 2, 4, 5, 8, 11, 12, 13; L 2; N 9.

LIE BELIN, LABORATOIRE INDUSTRIEL D'ELECTRONIQUE BELIN, 296 Av. Napoleon-Bonaparte, Rueil-Malmaison (S. and O.). Tel.: 967.15.54. T.A.: Belinusine Rueil.
Electronic instrumentation.
Scintillation detectors for atomic piles at Marcoule, Saclay, etc., CEA; Carbotrimetre (for measurement of low-energy emissions of β rays in liquid scintillators) for CEA, Saclay.
M 10; N 3, 7.

MACGREGOR COMARIN S.A., "Land Division," 15 Rue Henri Heine, Paris 16e. Tel.: BAGatelle 90–91. T.A.: Magromarain Paris. Telex: Macgregor Paris 20.891.
Jointing appliances.
Watertight dividing caissons for water pools in Israel and Grenoble (Siloe) for SFAC, Le Creusot and INDATOM, Paris; mobile liquid and gastight metallic covers to Saclay and Marcoule nuclear centres, CEA, and Chinon atomic power station, EDF; liquid and gastight doors for Saclay and Cadarache nuclear centres, CEA.
F 6, 12.

SOCIETE D'OPTIQUE ET DE MECANIQUE DE HAUTE PRECISION (SOM), 125 Bd. Davout, Paris 20e. Tel.: ROQ 81–85. T.A.: Sombertios Paris.
Hydraulic control equipment.
Heavy electro-hydraulic remote handling equipment, capacity: claws 50 kg, hook 500 kg, for LECI, CEN, Saclay; hydraulic remote handling equipment, capacity: claws 50 kg, for SCRGR, CEN, Saclay; 14 sets of equipment for surveying bubble chamber plates for various nuclear engineering labs in France, Sweden, Belgium, Holland and Switzerland.
G 4, 8; L 7, 8, 11; M 10.

POMPES RATIER (Department of C.S.F.), 97 Av. Pierre Brosselette, Montrouge (Seine). Tel.: ALE 69–60.
Water-tight pumps for primary and secondary circuits; special electric motors for nuclear industry.
F 7.

SOCIETE DE RECHERCHES TECHNIQUES ET INDUSTRIELLES (S.R.T.I.), 111 rue la Boetie, Paris 8e. Tel.: BALzac 54–55.
Isotopic separation: engineering for pilot plants, study and production of special materials, applied research; decontamination, engineering.
P 1, 2, 3.

SOGREAH, Av. Leon Blum, B.P. 145, Grenoble (Isere). Tel.: 44–55–30. T.A.: Sogreah Grenoble.
Studies and tests of all kinds, every technique in the field of fluid mechanics, thermodynamics and heat transfer as well as the construction of prototypes for equipment and/or the relevant installations.
Test loops for heavy water, CO_2, organic liquids, in-pile or out of pile; hydraulic transport of irradiated fuel elements (for CEA); continuous counter-flow regeneration of ion exchanger resins saturated with fission products for EDF 1, Chinon; design study of fluid circuits from the point of view of heat transfer, flow patterns, head losses, stability, vibrations, etc., for Melusine CEA, also EDF and Euratom.
F 14; H 5, 6; J 1; M 8, 9.

SOCIETE STEIN ET ROUBAIX, 24 rue Erlanger, Paris 16e. Tel.: JASmin 94.40. T.A.: Steinrou Paris.
Heat exchangers, industrial furnaces.
Experimental thermal loops, cooling by liquid metals, CEA; plant for filtration and conditioning of radioactive CO_2, cooling by pressurized gas at Chinon, for EDF; heat exchanger, pulverizing equipment for CEA; pulverizers for uranium ores.
F 14; H 2, 4, 5, 6.

SIERSATOM, 108 Avenue du Maine, Paris 14e. Tel.: SEGur 23–09. T.A.: Robispe Paris.
Radiation protection, handling, chemical laboratory apparatus.
Radioactive rod and waste disposal installation at EDF 1, Chinon; universal decanning machines; manual, semi-automatic and automatic, autoclaves for sterilization, glove boxes, ventilation hoods, lead casks, diaphragm valves for CEA, FIAT Junta Nucleare, Philips, Duphar, Alsthom, Faculty of Science Laboratory, Paris.
E 10, 11, 13; F 6; G 3, 4; H 6; L 2, 7, 8, 12; M 10, 11; N 1, 10.

SOCIETE ANONYME D'ETUDES ET REALISATIONS NUCLEAIRES, "SODERN," 10 rue de la Passerelle, Suresnes (Seine). Tel.: LONgchamp 15–81. T.A.: Sodern Paris.
Thermocouples, heating elements and sheathed cables for nuclear installations, data processing, electronic instrumentation.
Various thermocouples, heating elements and special cables for Saclay, Grenoble, Fontenay-aux-Roses, France, AGR Windscale, AEC U.S.A.
G 3 and 4.

SOCIETE DE RECHERCHES ET D'APPLICATIONS TECHNIQUES, (SRAT), 41 rue Emeriau, Paris 15e. Tel.: VAU 79–33. T.A.: Rechaplitec.
Portable electronic instrumentation.
H 4; N 2, 3, 4, 5, 6, 7.

TBT, Grenoble, B.P. 122, 80-82 rue Ambroise Croizat, Saint-Martin-d'Heres, Isere. Tel.: 44–60–42.
Hydrogen and helium liquefiers, storage vessels and transfer lines for nitrogen, hydrogen, helium, etc.; cold loops.
30 and 60 l/h hydrogen liquefier for bubble chambers, special cryostats for neutron diffraction at Saclay, CEN; special cryostats for neutronic diffraction for CEN of Algiers, Clarendon Laboratory Oxford; liquid nitrogen loop for study of radiation damage Avogadro swimming pool reactor, SORIN, Italy; liquid nitrogen loop for study of radiation damage, Triton swimming pool reactor, CEN, Chatillon.
M 8; P 3.

COMPAGNIE FRANCAISE THOMSON-HOUSTON, Department du Techniques Nucleaires, B.P. No. 11, Bagneux, Seine. Tel.: ALEsia 64–90.
Electronic equipment.
Nuclear instrumentation at Saclay, Chinon and several other nuclear centres.
G 1, 4, 8, 9; M 10; N 1, 10.

TREFILERIES ET LAMINOIRS DU HAVRE, 28 rue de Madrid, Paris 8e. Tel.: LABorde 73–20.
Metallurgical materials for nuclear fuels, studies of fabricating practices, development of less common metallurgical materials.
D 4, 5; K 2, 3, 4, 5.

VMDI (LE VIDE MOLECULAIRE DANS L'INDUSTRIE), ROGER GRESILLON AND CO., 48 rue Ramponneau, Paris 10e. Tel.: PYR 21–69.
Vacuum accessories and equipment.
Electric conductivity oven and fusion point oven for Saclay, CEN.
M 11.

GERMANY

ALLGEMEINE ELEKTRICITATS-GESELLSCHAFT, AEG-Hochhaus, Abt. Kernenergieanlagen, Frankfurt (Main) Sud 10. Tel.: Frankfurt (Main) 60521. T.A.: Electronkea.
Heavy and light electrical equipment, instrumentation, engineering services.
Complete turn-key nuclear power station at Kahl/Main (15 MW BWR-indirect cycle, natural circulation), together with US General Electric and Hochtief supplied to Versuchsatomkraftwerk Kahl, GmbH (Rheinisch-Westfälisches Elektricitätswerk und Bayernwerk); planning and construction of the research reactors Merlin and Dido and associated installations, together with Ruhrstahl AG, supplied to Kernforschungsanlage Jülich e.V. des Landes Nordrhein-Westfalen; supply of a 50 MeV deuteron-isochronous-cyclotron supplied to Gesellschaft für Kernforschung, Karlsruhe; complete instrumentation equipment for the Dido reactor supplied to Kernforschungsanlage Jülich e.V.
A 4; B 4; F 11; G 1, 2, 3, 4, 5, 6, 7, 8, 9; M 1, 2, 3, 6, 7, 11; N 4, 5.

AERZENER MASCHINENFABRIK GmbH, Aerzen ub Hameln, Reherweg 26-28. Tel.: 225. T.A.: Maschinenfabrik Aerzen. Telex: 9–2847.
Roots-type and screw compressors.
Blowers for CO_2 and helium supplied to France and Germany.
F 11.

ATLAS-WERKE AG, Abt. MAT, Bremen-Woltmershausen, Woltmershauser Str. 442/448a. Tel.: 35.57.57. T.A.: Atlaswerke.
Analytical instruments and research equipment.
Mass spectrometers, mass spectrometer leak detectors, membrane micro-manometers, high vacuum equipment.
N 9.

AUERGESELLSCHAFT GmbH, Berlin N 65, Friedrich-Krause-Ufer 24. Tel.: 35.05.71. T.A.: Auer Berlin 1.83.874.
Manufacturers of Auer-Ras protective clothing; fine, super-fine and ante filters for industrial ventilation systems.
H 4; L 9.

BERKEFELD-FILTER GmbH, CELLE, Celle. Tel.: Celle 5155. T.A.: Berkfilter Celle.
Water treatment and pre-coating filters.
Various plants for waste water retention; ion exchangers for water demineralization.
H 4, 5, 6.

WALTER BOLL FILTER GmbH, Koln-Ehrenfeld 2, Subbelrather Str. 407, Postfach 37. Tel.: 52.11.66.
Wire gauze filters for liquids; micro-klean filters.
Filters with micro-klean cartridges for heavy water supplied to OEEC reactor, Halden.
H 4.

OTTO P. BRAUN, Stuttgart-N, Kriegerstr. 4-6. Tel.: 29.72.41. T.A.: Braunserie.
Mineral insulated thermocouples; heating and lead cables.
Work for Interatom and Gesellschaft für Förderung der Kernphysikalischen Forschung, Aachen.
F 13; G 3.

BUCHLER AND CO., Braunschweig, Frankfurterstr. 294. Tel.: 2.53.15. T.A.: Herbuchler Braunschweig.
Radioactive preparations, sealed radioactive sources, radiation protection equipment.
L 3, 4, 6, 8, 12.

CEAG, CONCORDIA-ELEKTRIZITATS-AKTIENGESELLSCHAFT, Dortmund, Munsterstr. 231. Tel.: Dortmund 88.6.11. T.A.: CEAG Dortmund.
Air filters and dust collectors.
Air filters for intake and exhaust air for power reactor, Kahl (Krantz-Lufttechnik) and research reactors at Seibersdorf (Inges-Klimatechnik), Prater/Wien (Small and Cie), Argonaut Karlsruhe (Krantz-Lufttechnik), Zyklotron Karlsruhe (Maschinenfabrik Balcke A.G.); delivery of air intake and exhaust filters totalling about 300 000 m^3/h.
H 4.

Germany (contd.)

DEUTSCHE DELATTRE & LEVIVIER, Dusseldorf, Berliner Allee 26. Tel.: 10386. T.A.: Delev 858/7604.
Vessels, tanks and pipework.
Pressure vessel, pipework, EDF 1 and 2 from parent company.
A 2; D 1, 2, 4; E 3, 4, 5, 6, 7, 8, 9, 10, 11, 13; F 1, 2, 4, 14; H 1, 2, 7; L 13

DINGLERWERKE AG, Zweibrucken (Pfalz) und Bierbach (Saar). Tel.: Zweibrücken 3451. T.A.: Dingler Zweibrücken. Telex: 045 246.
Structural steel and hydraulic steelwork engineering; axial and radial flow fans; stop valves; construction of tanks, holders and apparatus.
Biological screen with base ring and central loop; supply of pressure building (in collaboration); design and construction of the pressure building, entire erection of the building and the reactor FR 2, for Reaktor Bau- und Betriebs GmbH, Karlsruhe; heat exchanger, reactor Dido, NRW, Kernforschungszentrum, Jülich.

DONGES STAHLBAU GmbH, Darmstadt, Mainzer Str. 55. Tel.: 74331. T.A.: Donges Stahlbau Darmstadt.
Steel structures, cranes, nuclear engineering plants, electric and pneumatically controlled gates, radiation protection doors, sluices, etc.
Exhaust air chimneys for radioactive air, isotope co-ordinate crane, for test power plant, Kahl/Main; de-activating plant for Karlsruhe; radiation protection doors, gas-tight and pressure resisting sluice gates for Jülich.
H 2, 7; K 14; L 1, 12, 13.

DRAGERWERK HEINR. UND BERNH. DRAGER, Lubeck, Moislinger Allee 53/55. Tel.: 25831. T.A.: Draegerwerk Luebeck.
Breathing protection apparatus.
Air filters, reactors, glove boxes, fume hoods to Karlsruhe, Jülich and isotope laboratories.
H 4; L 9.

DURRWERKE AKTIENGESELLSCHAFT, Ratingen. Tel.: 4421. T.A.: Duerrwerke.
Steam generating equipment.
F 14.

ELEKTROPHYSIK DR. STEPHAN, Bad Godesberg, Plittersdorfer Str. 72, Schliessfach 229. Tel.: Bad Godesberg 6.88.44. T.A.: Elektrophysik Badgodesberg.
Design and installation of complete isotope laboratories.
M 2; N 1, 2, 3, 4, 5, 6, 7, 10.

ELEKTROSCHMELZWERK KEMPTEN GmbH, Munchen, 22, Bruder Str. 10. Tel.: 22.99.91. T.A.: Electroschmelze.
Special metals; shielding material; boron carbide.

EMIL HELFFERICH NACHFOLGER, Kirchheim-Teck, Dettingerstr. 96. Tel.: Kirchheim-Teck 6346. T.A.: Flanschhelfferich.
Pipework; flanges.
Flanges made from stainless and acid resisting steel for Atom-Reaktor AG, Würenlingen, Switzerland.
F 3.

FARBENFABRIKEN BAYER AG, Leverkusen-Bayerwerk. Tel.: 3531. T.A.: Farbfabrik Leverkusen.
H 5, 6, 7; K 12.

FARBWERKE HOECHST AG, vormals Meister Lucius and Bruning, Frankfurt (Main) Hoechst. Tel.: 31051. T.A.: Farbwerke Frankfurtmain.
Radiochemicals, heavy water.
K 10; P 1, 2.

FERNSTEUERGERATE, Berlin-Britz, Jahnstrasse 68-72. Tel.: 62.04.51. T.A.: Telemeter.
Electronic instrumentation, remote handling.
M 6.

FRANK UND SCHULTE HANDELSGESELLSCHAFT mbH, Essen-Ruhr, Alfredstr. 154/156. Tel.: 44.40.01. T.A.: Silizium. Telex: 0857/835.
Metals, rare earth, aggregates for high density shielding concrete.
Magnetite for high density concrete, Triga reactor and hot cell, Vienna; barytes for high density concrete supplied to Isotopen Labor, Kernreaktor Karlsruhe, reactor Jülich, Great Britain, DESY, Deutsches Elektronen Synchrotron, Hamburg; shielding blocks density 4·0 t/cbm supplied to Synchrotron, Hamburg; shielding bricks density 4·1 t/cbm supplied to Kernreaktor, Karlsruhe.
K 7; L 3.

FRIESEKE AND HOEPFNER GmbH, Erlangen-Bruck, Tennenloher Str. 41. Tel.: 2551. T.A.: Frieseke Erlangen.
Radiation measuring instruments.
Radiation measuring instruments, radiation detectors, lead shields, trolley scanner, sample changers, recording equipment, vibrating reed electrometer, ionization chambers, radiation monitors, FH dosage calculator, air monitors, water monitors.
L 5; N 1, 2, 3, 4, 5, 6, 7, 8, 9.

GKSS, GESELLSCHAFT FUR KERNENERGIEVERWERTUNG IN SCHIFFBAU UND SCHIFFAHRT mbH, Hamburg 26, Normannenweg 10, Haus "Bosch-Dienst." Tel.: Hamburg 25.87.74.
Operators of Research Reactor Geesthacht near Hamburg, Institute for Reactor Physics, Institute for Nuclear Ship Propulsion.

TH. GOLDSCHMIDT AG, Essen, Postfach 17. Tel.: Essen 20161. T.A.: Stannum.
Production of rare earth compounds, in particular europium oxide.
J 3.

F. J. GATTYS INGENIEURBURO, Fränkfurt (Main), Vilbeler Str. 36. Tel.: 27957. T.A.: Gattys ffm.
Decontamination of waste water and air; transport and storage of radioactive materials; special designs; protective screen installations.
Waste water processing plant for the Physical Chemistry Institute, Bonn University; stopper pulling device for the Reactor Physics Institute, Frankfurt University; zinc bromide window for the Karlsruhe reactor.
G 5; L 2, 4, 13; M 11.

GRAETZ-RAYTRONIK GmbH, Altena/Westfalen, Graetzstr. Tel.: 821. T.A.: Graetzwerk Altenawestf.
Electronic instrumentation, count-rate meters.
G 1.

GRUN UND BILFINGER A.G., Mannheim, Karl-Reiss-Platz 1-5. Tel.: 4591. T.A.: Grünbilf.
Civil engineering and consulting.
Heavy concrete blocks for radiation screening supplied to the Technical University, Aachen and the Institute for General Metallurgy and Metal Physics.
L 3.

GUTEHOFFNUNGSHUTTE STERKRADE AG, Werk Sterkrade (22a), Oberhausen-Sterkrade. Tel.: 60141. T.A.: Hoffnungshuette Oberhausen-rheinlsterkrade.
Mechanical engineering, structural engineering.
Heat exchangers at Kahl, for AEG.
A 1; B 1; E 3, 4, 9; F 1, 2, 11, 14.

HARTMANN AND BRAUN A.G., Frankfurt a.M., Gräfstr. 97. Tel.: 77.06.11. T.A.: Hartmannbraun Frankfurtmain.
Measuring instruments and automatic control equipment; gas analysers; nuclear instruments.
Measuring and automatic control equipment (all nuclear channels) Research Reactor Frankfurt/Main; contract signed for delivery of complete nuclear and conventional measuring and automatic control equipment for Schulten high temperature power reactor at Jülich (1961).
E 6; G 1, 2, 3, 4, 7, 9; M 2, 5, 6, 10; N 1, 2, 3, 4, 5, 6, 7, 9, 10.

HENSCHEL-WERKE GmbH, Kassel 2, Henschelstr. P.O. Box 786. Tel.: Kassel 19211. T.A.: Henschel Kassel.
Containers for reactor feed water and sealing liquid; automatic steam generator and high-pressure steam generator up to 250 atm and 550°C, e.g., for testing materials and fittings; transfer trucks for fuel elements; transporters for radioactive bodies.
Lead container for changing of elements, transfer trucks and crane cross pieces for the test reactor, Kahl/Main; cylinders for element changing for AEG test reactor.
E 4, 5, 9; F 14; L 13.

HERFURTH GmbH, Hamburg-Altona, Beerenweg 6-8. Tel.: 89.33.63. T.A.: Herfurthphysik Hamburg.
Radiation measuring instruments.
Ion chamber instruments, G.M. rate meters; G.M. measuring instruments for alpha, beta, gamma; portable G.M. instruments of various design, stationary warning instruments with automatic switch-over of meter ranges; airborne radiation control instruments; instruments to simulate the thermic rays of nuclear weapons, supplied to reactor power stations, research reactors, accelerator plants, isotope laboratories, civil defence.
N 2, 3.

HOCHTIEF A.G., VORM. GEBR. HELFMANN, Frantfurt/Main, Bockenheimer Landstr. 24/26. Tel.: Frankfurt 720271. T.A.: Hochtief Frankfurt/Main. Telex: 11/210.
Buildings for atomic energy and research; high density concrete shields.
Entire construction work, concrete shields for the atomic power station Kahl/Main (first in Germany) for R.W.E. (Rheinisch-Westfälische Elektrizitätswerke AG), Essen/Ruhr.
E 1.

IGK-INGENIEURGEMEINSCHAFT KERNVERFAHRENSTECHNIK, LEYBOLD-LURGI-UHDE, Bonner Str. 504, Cologne-Bayental. Tel.: 4716. T.A.: Leybolding.
Planning and building hot laboratories, reprocessing units, waste storage and treatment.
L 1.

INTERATOM, INTERNATIONALE ATOMREAKTORBAU GmbH, Bensberg, Nr. Cologne. Tel.: Bensberg 3091. T.A.: Interatom Bensberg.
Design and construction of nuclear reactors; design and manufacture of equipment for industrial application of radioisotopes.
Design and development contract for OMR ship reactor for GKSS.
A 5; B 1, 2, 5; P 2.

JENAER GLASWERK SCHOTT AND GEN., Mainz, Hattenbergstr. 10. Tel.: Mainz 81.61. T.A.: Glaswerk Mainz. Telex: 0417.849.
Special glasses for optical and laboratory purposes, chemical industry, nuclear physics.
Radiation shielding window assembly, complete with steel frames and oil filling for Saluggia, SORIN.
L 4.

KBWP, P.O. Box 158, Stuttgart 1. Tel.: 29.12.48. T.A.: Schwabenwerk. Telex: 072/3715.

GEWERKSCHAFT KERAMCHEMIE, Siershahn/Westerwald. Tel.: Ransbach 254. T.A.: Keramchemie Siershahn. Telex: 086316.
Chemical and corrosion resisting materials, apparatus, plant and equipment.
Acid-resisting linings for cooling towers and battery rooms, Kernreaktor Karlsruhe/Leopoldshafen; ARGE Reaktorgebäude, Leopoldshafen; plastic linings in storing pits for effluents from isotope laboratories supplied to Dr. Karl Thomae GmbH, Biberach/Riss; plastic linings in test rooms for the Max Planck-Institut für Biophysik, Frankfurt/M.
E 12.

KERNREAKTOR BAU-UND BETRIEBS GESELLSCHAFT mbH, Karlsruhe, Weberstr. 5. Tel.: 26825. T.A.: Reaktor Karlsruhe.
Reactor operator and consultants in nuclear energy.

KLOECKNER-WERKE AG GEORGSMARIENWERKE, Osnabrueck-Georgsmarienhuette. Tel.: Osnabrueck 9021.
Steel production.
Special forging steel for the power test reactor, Kahl.
D 1, 2, 3; E 3, 4, 9, 12, 13; K 14.

AUG. KLONNE, Dortmund, Koernebach Str. 1. Tel.: 52.77.61. T.A.: Klönne Dortmund.
Steel structures, tanks and gasholders.

ALBERT KNOTT, Munchen 23, Muffatstrasse 8. Tel.: 331480. T.A.: Knottelektronik München. Telex: 05/22312.
Nuclear physics and radiation measuring instruments, nuclear monitoring plants, special parts for nuclear physics.
Large area monitoring plant for Karlsruhe reactor; monitoring plants for Geesthacht and Siemens, München, reactors.
G 4; M 5; N 1, 2, 3, 4, 5, 6, 7, 10.

KROPFMUHL-RINGSDORFF AG FUR SONDERGRAPHITE, Bad Godesberg-Mehlem, Postfach. Tel.: Bad Godesberg 12001. T.A.: Kohlebürste Bad Godesberg.
Fabrication of nuclear grade graphite.
Graphite for thermal columns, Karlsruhe reactor, supplied to Reaktor-Bau-u. Betriebs GmbH, Karlsruhe; graphite for exponential experiments, CERN, Geneva, Meyrin.
K 8.

LABORATORIUM PROF. DR. R. BERTHOLD, Wildbad im Schwarzwald, Calmbacherstrasse 22. Tel.: Wildbad 587. T.A.: LABE Wildbad.
Electronic instrumentation, radiation monitors.
Hand and foot monitors supplied to Kernreaktor Karlsruhe and Jülich; air monitoring equipment supplied to Kernreaktor Karlsruhe and Kahl (Main).
N 1, 2, 3, 4,7.

Germany *(contd.)*

DR. BRUNO LANGE, Berlin-Zehlendorf, Hermannstr. 14-18. Tel.: 84.30.51· T.A.: Photozelle Berlin.
Photo-electric measuring and control instruments.
Multiflex-galvanometers of all types to Institut für Kernforschung Prof. Hahn Weitner, Berlin-Wannssee; flame photometer and universal-colorimeter (Kernreaktor Bau-u. Betriebs GmbH), Techn. Abteilung, Karlsruhe.
N 10.

E. LEITZ GmbH, Wetzlar/Lahn, Ernst-Leitz Str. Tel.: 851.
Optical and mechanical instruments.
M 10.

LEWA, Leonberg, Nr. Stuttgart, Ulmer Str. 10. Tel.: 7241. T.A.: Lewa Leonbergwuertt.
Proportioning pumps; remote control and fully automatic operating proportioning systems.

LEYBOLD-HOCHVAKUUM-ANLAGEN GmbH, Bonner Str. 504, Cologne-Bayental. Tel.: 4716. T.A.: Leybolding.
Design, engineering and construction of special installations in the high vacuum and nuclear engineering fields.

GESELLSCHAFT FUR LINDE'S EISMASCHINEN AG, Zweigniederlassung Hollriegelskreuth, Hollriegelskreuth bei Munchen. Tel.: München 79.06.55. T.A.: Sauerstoff Muenchen.
Plants for the production of deuterium; purification plants for reactor coolant gases and protection gases; refrigeration plants down to liquid helium temperature.
Contract to supply a helium purification plant for the Dragon project, to C. A. Parsons and Co., Ltd., Newcastle.

E. MERCK AG, Darmstadt. Tel.: 8021. Telex: 4–19225 merck dmst 1.
High purity materials.
Radiochemically pure U and Th compounds; phosphors, lead perchlorate shielding solutions.
L 4; N 6.

METALLGESELLSCHAFT AG, Frankfurt a. M., Reuterweg 14, P.O. Box 2609. Tel.: 55.05.71. T.A.: Metallbank Frankfurtmain. Telex: 04/1225.
Non-ferrous metals, non-ferrous metal ores, pyrites, phosphates, sulphur, boron products, sulphuric acid, business in technological processes, production of super-purity metals.
K 2, 4, 15.

NUCLEAR GmbH, Kernphysikalische Anlagen f. Medizin und Technik, Dusseldorf, Florastr. 16. Tel.: 1.93.77. T.A.: Nuclear Düsseldorf.
Gamma radiation equipment for kilocurie sources for research and industry; medical equipment, gammaradiographic units.
Gamma irradiation equipment 5 000 curies to BASF, Ludwigshafen and Physik. Institut d. Univ. Köln; gamma irradiation equipment for medical purposes, 30 curie, to Münster University.
P 2, 3.

NUKEM, NUKLEAR-CHEMIE UND METALLURGIE GmbH, Wolfgang bei Hanau (Main). Tel.: Hanau 6911 (Degussa). T.A.: NUKEM Wolfgang.
Nuclear fuel and breeder material of natural and enriched uranium as well as of thorium; metals, oxide, carbide and cermet elements for research, test and power reactors also reflector elements and others.
Fuel elements with 20% enriched U^{308} for Argonaut reactor, to AEG, Grosswelzheim; fuel elements with 20% enriched U^{308}, Argonaut reactor, Kernreaktor Bau.u Betriebs GmbH, Karlsruhe; thorium breeder elements, FR–2, to Kernreaktor Bau.u Betriebs GmbH, Karlsruhe; pebble bed fuel elements with enriched UC for high temperature reactor, BBC/Krupp, Jülich; polyethylene elements with 20% enriched U^{308}, SUR–100, BBC/Krupp, Jülich; reflector elements with beryllium oxide, Merlin, to Gesellschaft für Kernphysikalische Forschung, Jülich; uranium metal fuel elements, Diorit, to Eidg. Institut für Reaktorforschung, Switzerland.
C 1, 2, 3, 4, 7; J 1, 2, 3.

P.E.K. ELECTRONIC DR.-ING. PAUL E. KLEIN, Tettnang/Wurtt, Postfach 80. Tel.: (07542)–347. T.A.: Dr. Klein Tettnang.
Electronic instrumentation (measuring instruments).

PHOENIX-RHEINROHR AG, Vereinigte Huetten und Roehrenwerke, Duesseldorf, August-Thyssenstr. 1, Thyssenhaus. Tel.: 8241. T.A.: Phoenix-Rheinrohr Duesseldorf. Telex: PhxRohr dssd 08581 421.
Pipework and steel.
Containers for decontamination solution for Kahl; pipes, plated metal sheets, heavy plates for reactor pressure vessel for the reactor station at Karlsruhe; pipes for heat exchanger for Jülich reactor station.
D 1, 3; E 3, 4, 7, 8, 9, 12; F 1, 2, 3, 14; K 14; N 8.

PHYSIKALISCH-TECHNISCHE WERKSTATTEN DR. PYCHLAU KG, Freiburg i.Br., Lorracher Str. 7. Tel.: 31710. T.A.: PETEWE Freiburg-breisgau.
X-ray detectors, survey-meters, health monitors, dose and dose rate meters.
N 2, 3.

PHYWE AG, Gottingen, Schliessfach 665. Tel.: 24338. T.A.: Phywe Göttingen. Telex: 096808.
Scientific equipment for schools and laboratories.
Instructional atomic physics aids for demonstrating selected experiments in advanced schools, colleges and universities.

PINTSCH BAMAG AG, Butzbach/Oberhessen, P.O. Box 11 (Wetzlarerstr.). Tel.: Butzbach 4101. T.A.: Bamag Butzbach.
Decontamination, waste disposal.
Cleaning of circulation system, circulation and reflux cooling, coolers, ion exchangers, containers, etc., for Kernreaktor Bau- und Betriebs GmbH, Karlsruhe; decontamination plant for Hahn-Meitner-Institut, Berlin-Wannsee; de-salting of make-up water for the primary circulation system; processing plant for circulation system water, for the reactor station, München-Garching; decontamination plant for the Institut für Physik und Meteorogie, Stuttgart-Hohenheim.
F 14; H 2, 4, 5, 6, 7.

POETSCHKE & CO. OHG, Frankfurt/Main 1, P.O. Box 2766. Tel.: 0611/551688. T.A.: Nuclear Frankfurtmain.
Health monitoring, electronic instrumentation, consulting engineers.
Radiation measuring and monitoring equipment, survey meters, digital printers, water control, air particle monitors, sample changers, etc., to Versuchsatomkraftwerk Kahl GmbH, VAK, AEG, Kernreaktor GmbH, Karlsruhe, Institut für Kernphysik der Universitat Frankfurt/Main.
L 3, 9; M 5; N 1, 2, 3, 4, 5, 6, 7, 9.

REICHERT-ELEKTRONIK GmbH & CO. KG, Trier, Petrisberg/P.O. Box 743. Tel.: 3373. Telex: 04.7761.
Electronic instrumentation.
Pulse height analysers; α, β counters; flow counters; height-speed pulse generators and high speed oscilloscopes, etc.
M 4, 5; N 2, 3, 5, 6, 7, 10.

ROCHLING'SCHE EISEN- UND STAHLWERKE GmbH, Volklingen/Saar. Tel.: 35.11. T.A.: Rochling Volklingen. Telex: 42.591.
Steels and alloys in the form of castings, forgings, bar steel and strips; high-grade and special steels.
D 3; G 6; K 6, 14.

SIEMENS-SCHUCKERTWERKE AG, Abteilung Reaktor-Entwicklung, Erlangen, Schillerstr. 62. Tel.: 811. T.A.: Siemenschuckert Erlangen.
Research and power reactors, components for same, particle accelerators.
Research reactor—Siemens-Argonaut Reactor, to KBB (Kernreaktor Bau-u. Betriebsges, mbH); condensers, magnets, electrical equipment for a nuclear accelerator (electron synchrotron), DESY (Deutsches Elektronen-Synchrotron, Hamburg); rotary converters and precision control equipment, rectifiers, condensers, magnets, switchgear installations, electrical equipment for a nuclear accelerator (proton synchrotron, synchro-cyclotron) for CERN.
A 2, 4; B 2, 3; G 6, 7, 9; M 1, 2, 3, 8, 9.

SIGRI-KOHLEFABRIKATE GmbH, Meitingen uber Augsburg. Tel.: Meitingen 321. T.A.: Sigri—Meitingen.
Production of reactor graphite for moderators, reflectors, thermal columns and experimental measuring equipment, impermeable graphite for reactor purposes.
Nuclear grade graphite for an exponential pile, AG BBC-Krupp, Deutsche Babcock and Wilcox, Österr. Studiengas. f. Atomenergie; moderator and reflector for Argonaut Reactor, Siemens-Schuckertwerke, Garching, Technische Hochschule, Barcelona and Bilbao, AEG Argonaut, Gross-Welzheim; reflector for Dido reactor, Kernforschungsanlage Jülich; thermal column for Forschungsreaktor FR–2, Karlsruhe.
B 1; C 1, 5; D 7; K 8, 9.

STAHL UND ROHRENWERK REISHOLZ GmbH, Dusseldorf-Reisholz. Tel.:Düsseldorf 7.02.71. T.A.: TW 2821 Stahlreisholz Düsseldorf.
High pressure vessels, thick walled tubes and pipe system components; steel for nuclear components; heat exchangers.
Thick walled tubes for high-pressure piping; tube turn forged in two parts for heat exchanger at Kahl power station.
D 1, 3; E 4, 8; F 1, 2, 14; K 14.

OPT. WERKE C. A. STEINHEIL SOHNE GmbH, Munchen 8, Germersheimerstr. 10. Tel.: 44.45.23. T.A.: Optik München.
Lenses, optical instruments, especially spectrographs.
1 universal spectrograph GH, 1 ditto with special equipment, 1 bubble chamber, among other equipment for measurement of temperatures in plasma for the Max Planck Institut für Physik und Astrophysik, München; spectrum projector comparators to Euratom at Brussels and Ispra; 3 spectrum projector compartors to CEA, Paris.
M 10; N 10.

L. AND C. STEINMULLER GmbH, Gummersbach. Tel.: 2851 Gummersbach. T.A.: Steinmüller Gummersbach.
Steam boilers.
Decontamination plant for Reaktor Karlsruhe, Reaktor Bau-u. Betriebs Ges., Karlsruhe.
F 14; H 5, 6.

STOLBERGER ZINK AG FUR BERGBAU UND HUTTENBETRIEB, Aachen, Theaterstr. 37. Tel.: Aachen 48.13.1. T.A.: Stolbergzink. Telex: 08/32850.
Lead-coating of containers for transportation of radioactive elements.
E 5, 12; K 15.

ARBEITSGEMEINSCHAFT FUR STRAHLENSCHUTZ, Freiburg i. Br., Albertstr. 23. Tel.: 35244.
Instrumentation, health monitors.
Continual evaluation service on 6 000 persons for various reactors in Germany and medical users (X- and rays).
N 2.

TELEFUNKEN GmbH, ANLAGEN-HOCHFREQUENZ, Ulm/Donau, Elisabethenstr. 3. Tel.: 6.19.21. T.A.: Teleanlagen Ulm. Telex: 07/12723.
Electronic instrumentation.
N 1, 3, 7, 10.

VEREINIGTE BLEIWERKE GmbH, Werk Jung und Lindig, Hamburg-Eidelstedt, Schnackenburgallee 221. Tel.: Hamburg 544461. T.A.: Bleiwerke.
All types of protective screens made from lead; lead bricks, walls, plates, pipes, containers, portable containers; lead apertures, etc.
K 15, 16; L 3, 4, 13.

VEREINIGTE KESSELWERKE AG, Dusseldorf, Werdnerstr. 3. Tel.: 7.42.61. T.A.: Kesselwerke Düsseldorf.
Boiler manufacture.
F 14.

VERSUCHSANLAGE FUR URANERZVERARBEITUNG DER GEWERKSCHAFT BRUNHILDE, Buschhof Post, Uetze/Hannover. Tel.: Uetze/Hannover 271, 471. T.A.: Telex 092679.
Uranium concentrates; radiation measuring instruments; prospecting for other firms at home and abroad; advice and planning for uranium ore processing plants.
N 3.

DR. VIRUS KERNTECHNIK GmbH, Bonn, Rosenburgweg 20. Tel.: 2.4924·
Laboratory nucleonic electronic instrumentation.
Nucleonic and general laboratory equipment to various institutes of research and industry.
A 1; G 1, 2, 4, 6; L 3, 13; M 1, 2, 3, 5; N 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; P 1, 2.

WALBERSDORF, Sondermaschinenbau, Siegen/Westf. Tel.: Siegen 22306.
Development of dosing pumps for minimum capacities with constant delivery for radioactive liquids.
F 9.

HANS WALISCHMILLER, Meersburg/Bodensee, Am Furstenhausle 8. Tel.: Meersburg 223. Telex: 0733/297.
Remote handling equipment.
L 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13.

WALTHER & CIE, Koln-Dellbruck, Walther Str. 51. Tel.: 6731. T.A.: Waltharius.
Steam separators, steam generators, gas separators, superheaters, economizers, heat exchangers, materials testing, radiation sources, accessories, non-destructive materials testing.
F 14; N 8.

WAYSS AND FREYTAG, P.O. Box 2129, (16) Frankfurt a. M. Tel.: 2.00.11. T.A.: Wayssfreytag Frankfurtmain. Telex: 04/11421.
Concrete and steel concrete work (also reinforced concrete); supply of bricks for protective screens.
L 3.

ITALY

AGIP NUCLEARE SpA., Corso Venezia 16, Milan. Tel.: 53–53. T.A.: Agip Nucleare Milan.
Planning of nuclear power stations and nuclear reactors.

ACCIAIERIA E TUBIFICIO DI BRESCIA, Via Zara 12, Brescia. Tel.: Brescia 53361. T.A.: Atub.
Heavy plate fabrication, pressure vessels and drums.
Steam drum, demineralization vessel, 30-in piping for Garigliano power station, International General Electric.
E 4, 6; F 1.

BREDA TERMOMECCANICA E LOCOMOTIVE SpA., Casella Postale 3778, Milan. Tel.: 69.97. T.A.: Breda Termolocomotive Milan. Telex: 054.
Boiler manufacture, general fabrication.
E 4, 5, 6, 7, 8, 9, 13; F 1, 2, 4, 14.

CAREM, Corsico (Buccinasco), Via della Resistenza, Milan. Tel.: 83.93.673. T.A.: Carem Corsico.
Laboratory equipment.
L 2.

COMITATO NAZIONALE PER L'ENERGIA NUCLEARE, Via Belisario 15, Rome. Tel.: 460.900. T.A.: Nucleare Rome.
Applied and fundamental nuclear research, design and construction of reactors and other nuclear plants.

DALMINE SpA., Milan, Via Brera 19. Tel.: 88.58. T.A.: Tubidalmine.
Steel piping.
Special quality and prefabricated piping, general service collectors and mains, for Latina plant, Agip Nucleare; Garigliano Power Station, SENN; Ispra Nuclear Power Plant, Euratom.
E 7, 8; F 1, 3, 14.

FIAT SpA, Sezione Energia Nucleare, Via Settembrini 235, Turin. Tel.: 396.953. T.A.: Nuclearfiat Turin.
General fabrications, specialist materials, instrumentation.
Remote handling equipment and measuring equipment for CNEN and Euratom.
G 1; L 1, 2, 4.

GILARDONI SpA, Apparecchiature Radiologiche e Nucleari, Via Statale, Mandello Lario (Como). Tel.: 71.221. T.A.: Gilraggi Mandello Lario.
Radiological and nuclear apparatus for medical purposes; apparatus for all types of non-destructive testing.
Cobalt bombs, isotope containers, Gilatron 10, to F.lli Grandis, Siracusa; Besagni, Milan; Sincat, Siracusa; (medicine) Gilatron 3 000 to Centro Lom. Radium, Milan; Ospedale di Lecce; Istituto di Cura, Pavia; Casa Cura Villa Dieta Verona; Ospedale Civile, Prodenone; (industry) Gilatron 45 to Techider, Milan; Gilatron 10 to Ansaldo SpA, Genoa.
L 5, 13; N 8; P 2.

IMPER, Ing. A. Schieroni and Figli snc, Via Lanzo 131-133, Turin. Tel.: 25.40.54. T.A.: IMPER Turin.
Special piling for foundations for Garigliano, SENN, and Trino Vercellese, SELNI.
L 10.

FRATELLI KORISTKA SpA, Via Ampere 43-45, Milan. Tel.: 29.24.45. T.A.: Koristka Milan.
Nuclear track scattering microscopes to Italian Universities; Punjab University; The Weizmann Institute, Rehovoth (Israel); Metrimpex, Budapest; universities and research institutes in U.S.A.; histophotometers to the University of Minas Gerais, Belo Horizonte (Brazil), and Italian universities.
M 10.

LABEN, Srl, Laboratori Elettronici e Nucleari, Via Bassini 15, Milan. Tel.: 23.64.101. T.A.: Laben Milan.
Electronic instrumentation.
200 channel pulse height analysers for the swimming pool reactor, Saluggia, SORIN (1); protonsynchrotron, Geneva, CERN (2); electronsynchrotron, Frascati (Italy) (2), and Triga reactor, Casaccia (Italy), CNEN (3); C P 5 reactor, Ispra, Euratom (4); 256 channel pulse height analysers to Triga reactor, Casaccia, CNEN (1); C P 5 reactor, Ispra, Euratom (1); also millimicrosecond time analyser to C P 5 reactor (1).
M 4, 10; N 1.

MAGRINI SpA, Via L. Magrini 7, Bergamo. Tel.: 35.444. T.A.: Elettromagrini.
Switchboards of all types; equipment for low, medium and high tension up to 380 kV.
Panels for control and power centres, metal clad type, internal and external for the electronsynchrotron at Frascati, Italy, for the Instituto Nazionale di Fisica Nucleare; reactor at Ispra, CNEN; the thermoelectric power plant at Latina, SIMEA; plant at Mol, Belgium.
G 4.

NUOVO PIGNONE SpA, Via Panciatichi 97, Florence. Tel.: 27.92. T.A.: Nuovopignone Firenze.
Compressors, centrifugal pumps, boilers, vessels, tanks, heat exchangers, etc.

SOC. ACC. SEMPL. RIVA AND MARIANI, Via Fatebenefratelli 5, Milan. Tel.: 65.24.19. T.A.: Rivamarian Milan.
Manufacture, supply and installation of thermal insulation.
Thermal insulation to Latina Nuclear Power Station, SIMEA, Agip Nucleare, C. A. Parsons, Ltd.
E 13.

SACE SpA, COSTUZIONE ELETTROMECCANICHE, Via Baioni 35, Bergamo. Tel.: 38444. T.A.: SACE Bergamo.
Switchgear.
L.V. prefabricated boards, type Unimeta equipped with circuit-breakers, 150 to 600A and L.V. moulded case circuit-breakers, 150 to 600A for Latina, SIMEA, Milan and La Telemeccanica Elettrica, Milan; L.V. prefabricated boards, type Unimeta, equipped with circuit-breakers up to 4 000A for Ispra, Euratom.

SELNI, SOC. ELETTRONUCLEARE ITALIANA, Foro Bonaparte 31, Milan. Tel.: 8835. T.A.: SELNI Milan.
Design, construction and operation of a nuclear power station; at present engaged on construction at Trino Vercellese (North Italy), of a 165 MW(e) nuclear power station of the pressurized water type.

SELO, SOCIETA' ELETTRONICA LOMBARDA, Via Monfalcone 12, Milan. Tel.: 28.67.55.
Nuclear electronic equipment for laboratory, health physics and medical use.
Continuous air monitor for Casaccia Nuclear Centre, Rome; alpha spectrometer with ionization chamber for RAU Atomic Energy Commission; 5 complete laboratories (scalers, ratemeters, detectors, multi-channel) for Ispra Centre, Euratom; many complete laboratories to universities; 10 alpha spectrometers with ionization chambers for Frascati Nuclear Centre, Rome; 3 low background systems for the SORIN reactor health physics department.
G 2; M 10; N 1, 2, 3, 4, 5, 7.

TERMOMECCANICA ITALIANA SpA, Via del Molo 1, La Spezia, Casella Postale 232. Tel.: 23.251. T.A.: Termomeccanica La Spezia.
Water treatment, pumps, air conditioning, air compressors.
Make-up water treatment plant (pre-treatment and demineralization), waste water demineralization, regenerators for Garigliano Nuclear Power Station, IGEOSA, Rome; make-up water treatment plant (demineralization and softening), make-up radioactive discharge collection plant, for swimming pool reactor, CAMEN, S. pietro a Grado, Pisa, for Vitro Italiana, Milan.
H 5, 6.

TERNI, SOC. PER L'INDUSTRIA E L'ELETTRICITA, Via Due Macelli 66, Rome. (Viale B. Brin, 218, Terni.) Tel.: 689.351. (20.101). T.A.: Ellettroterni Roma.
Steel forgings, castings and heavy plate fabrication.
Reactor pressure vessel, heat exchangers, emergency condenser, spherical container, electrical generator shaft (Ansaldo S. Giorgio, Genoa) for Garigliano (International General Electric Operation S.A.); heat exchanger flanges for Latina SIMEA (Agip Nucleare).
D 1; E 4, 6, 9; F 4, 14; K 14.

DOTT. ING. GIUSEPPE TORNO AND C. SpA, Via General Albricci 7, Milan. Tel.: 80.27.41. T.A.: Idrotorno.
Civil engineering.
Civil engineering works for Latina, SIMEA.

FRANCO TOSI SpA, Legnano (Milan), Corso Italia 27. Tel.: 47690. T.A.: Tosi Legnano.
Steam boilers and turbines.
3 main steam condensers, F.W. heaters, condensate pumps for Latina, SIMEA; 180 MW main steam turbine and condenser for Trino Vercellese, SELNI, Milan; steam drum for Garigliano, SENN, Rome.
F 1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 14.

VITRO ITALIANA SpA, Via Baldissera 5, Milan. Tel.: 26.50.37. T.A.: Vitroworld Milano.
Design and construction of industrial installations, specializing in nuclear, chemical and metallurgical plants.
Nuclear reactor, Accademia Navale, CAMEN, Livorno; hot cells installation, CNEN, Casaccia, Rome.

LIECHTENSTEIN

BALZERS AG, fur Hochvakuumtechnik und Dunne Schichten, Balzers, Furstentum, Liechtenstein. Tel.: 075/4.11.22. T.A.: Interferencia.
High vacuum equipment.
High vacuum pumping units and high vacuum melting, casting and sintering furnaces.

NETHERLANDS

MIJ. AGO N.V., Lignostone-Fabriek, Ter-Apel. Tel.: 454 (05995). T.A.: Ago Ter Apel.
Lignostone (artificial hardwood) for neutron shields for RCN, Petten and Institutt for Atomenergi, Kjeller, Norway.
L 3.

APPARATEN-EN KETELFABRIEK DEN HAAG N.V., Fruitweg 28, The Hague. Tel.: 070/33.39.15. T.A.: Apparafa.
Chemical equipment specializing in the following materials:—Hastelloy B and C, nickel, monel, stainless steel, silver, lead, clad steel, copper.
2 organic coolant test loops, NaK corrosion test loop, distilled water cooling system for Ispra, Euratom.
A 1, 2; D 1, 2, 3, 4, 5, 6, 7; E 3, 4, 5, 6, 7, 8, 9, 12, 13; F 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14; H 2, 3, 4, 7; L 13; M 7, 8, 10, 11.

TECHNISCH HANDELS-EN WATERZUIVERINGSBUREAU "AQUAPUR" Marquette 26, Amsterdam-Z II. Tel.: 020/42.09.00. T.A.: "Aquapur" Amsterdam.
Water conditioning plants; chemical plants, pipe-lines of steel, ebonite, plastics, stainless steel, aluminium, etc., measuring and regulating equipment, air, gas and steam purifiers.
Complete water demineralization plants with piping, pressure vessels, pumps, filters, and regulation equipment for swimming pool reactor, Reactor Institute, Delft, Curatoren der Technische Hogeschool, Delft, (Comprimo N.V., Amsterdam).
E 4, 5, 8, 9, 12; F 3, 5, 6, 7, 8, 14; G 9; H 2, 4, 5, 6, 7.

N.V. MACHINEFABRIEK "ARNHEM," Nieuwe Havenweg 9, Arnhem. 08.300–23746.
Apparatus in stainless, aluminium and other alloy steels.
Helium purification plant for the Dragon project with pressure vessels in stainless and carbon steel; bellows sealed valves; various apparatus for the DEMA project at Arnhem.
E 9; F 12.

BAIRD-ATOMIC (HOLLAND) N.V., 5A Hartogstraat, The Hague. Tel.: 070/11.39.59. T.A.: Bairdco Den Haag.
Electronic instruments for nuclear measurements, especially gamma spectrometry.
N 1, 2, 7.

BRANSON EUROPA N.V., Industrieweg 14A, Loosdrecht. Tel.: Loosdrecht 13.61. T.A.: Branson Loosdrecht. Telex: 12086.
Ultrasonic cleaning and testing equipment.
Zirconium tube gauging, uranium and nuclear component gauging, radioactivity decontamination installation for various installations.
N 8.

MACHINEFABRIEK "BREDA" V/H BACKER EN RUEB, Speelhuislaan 173, Breda. Tel.: (01600)–2.42.81. T.A.: Machinefabriek. Neratoom N.V.
Boilers, chemical plant, lifts and escalators, pumps, electro-technical installations.
A 1, 2, 3; D 1, 2; E 4, 5, 9; F 1, 2, 3, 14; G 9.

N.V. BRONSWERK, Amersfoort. Tel.: 03490–45.42. T.A.: Bronswerk Amersfoort. Telex: 11039.
E 3, 4, 6, 7, 9; F 1, 2, 3, 4, 11, 14; H 3.

CHAMOTTE UNIE N.V., Geldermalsen. Tel.: (03455)–4.43. T.A.: Chamotte.
Refractories, acid proof cements, coating materials (radiation and decontamination resistant).
E 12.

G. DIKKERS & CO. N.V., Hengelo (0). Tel.: (05400)–33.44. T.A.: Dikkers Hengelo.
Valves.
Valves for SENN nuclear power station, Italy.
F 5, 6, 10.

DUPER WATER CONDITIONING CO., Nieuwendammerkade 1-3, P.O. Box 196, Amsterdam-N. Tel.: 60821. T.A.: Waterduper.
Water conditioning plants.
Decontamination installation for radioactive waste water (from hot lab., etc.), ion exchange treatment for primary loop water, high flux reactor, ion exchange treatment for pool system for RCN, Petten.
H 4, 5.

Netherlands (contd.)

FISCHER & PORTER, Koninginnengracht 12, The Hague. Tel.: 72.01.50. T.A.: Fishnet The Hague.
Process instrumentation, laboratory equipment.
Various flow instruments, chlorinator for RCN, Petten.
G 4, 9.

W. C. 'tHART & Zn., INSTRUMENTEN-EN APPARATENFABRIEK N.V., Adrianalaan 380, P.O. Box 3002, Rotterdam. Tel.: 18.00.60. T.A.: Hartco Rotterdam.
High pressure equipment such as compressors, balances, pressure vessels, valves.
Goniometer drive for Petten, RCN; control rod drive also for RCN.
F 5; G 4.

IMACTI INDUSTRIEELE MIJ. ACTIVIT N.V., Nieuwendammerkade 1-7, P.O. Box 240-C, Amsterdam-N. Tel.: 60821. T.A.: Activit Amsterdam. Telex: 14.278 Sulfuracid.
Manufacture of IMAC-ion exchange resins and ASMIT-decolourizing resins.
H 5.

IR. H. J. JONGEN, Vlaardingen, Schiedamsweg 103. Tel.: (0.18.89) 63,48.
Consulting engineers.
Associated with E. G. Irwin and Ptrs., Ltd., London, S.W.1.

REFORM ISOLEERBEDRIJF "ISOLA" N.V., 30-32 Wandelpad, Hilversum. Tel.: 42341. T.A.: Isola. Telex: 14346.
Installation of insulation materials, of corrosion and radiation protection materials, of polyester finishes, metal lining.
Thermal insulation work at Delft Reactor Centre.
E 3, 12, 13; F 10.

"JARO," Alkmaar, Heiloerdijk 30. Tel.: K 2200–8244. T.A.: Jaro Alkmaar.
Piping, tanks, reactor vessels, in aluminium, also other special materials: monel, nickel, hastelloy, copper and clad material.
Containers (RCN), heat exchangers and various components (Philips, Eindhoven) for Petten.
E 3, 4, 9; F 1, 2, 3, 4, 5; 14.

KOOPMAN & CO., TECHNISCHE HANDEL-MIJ. N.V., Stadhouderskade 6, Amsterdam (W). Tel.: 82821. T.A.: Kjoebmand Amsterdam.
Irradiation facilities.
10 c caesium container for irradiation cells, Inst. Radioth., Leiden; 200 c caesium container for irradiation cells, Radiobiologisch Lab., T.N.O., Rijswijk, Holland.
A 4; M 2; P 2, 3.

VAN LEER'S VATENFABRIEKEN N.V., P.O. Box 25, Amstelveen. Tel.: 020/730855. T.A.: Leervat Amstelveen. Telex: 11337.
Manufacture and sale of polyethylene drums and tanks for radioactive waste.
Valethene drums to RCN, Petten and Instituut voor Kernphysisch Onderzoek, Amsterdam.
H 7.

N.V. LEIDSCHE APPARATENFABRIEK, Os- en Paardenlaan 41-43, Leiden. Tel.: (01710)-3.07.45. T.A.: Ellaef.
Equipment for the chemical industry in light alloy, stainless steel and other special materials.
Primary cooling tank for ACF, Sweden; racks for RCN and ACF; pipelines, vessel emergency/cooling assembly for RCN.
E 3, 4, 6, 7, 9; F 1, 2, 3, 14; H 2, 4, 5.

N.V. NERATOOM, Noordeinde 38, The Hague. Tel.: 115661. T.A.: Neratoom The Hague.
Heavy plate fabrication; boiler manufacture; welding; pressure vessels; heat exchangers; heavy forgings; electronic instrumentation
Steam generators for SENN project, core structure for General Electric; core structure for Dragon, OEEC High Temperature Reactor Project; pressure vessels and components for Neptunus Project, combined research group—Technical University, Delft, Royal Netherlands Navy.
A 1, 2, 3; B 2, 3, 4; D 1, 2, 3, 4; E 3, 4, 6, 7, 8, 9, 10, 11; F 1, 2, 3, 7, 11, 14; G 1, 3, 4, 9; H 2; M 1, 2, 6, 7, 10, 11; N 1, 2, 3, 4, 5, 6, 7, 8; P 1, 2.

NIEAF, N.V. NEDERLANDSCHE INSTRUMENTEN- EN ELECTRISCHE APPARATEN FABR., Jutfaseweg 205, Utrecht. Tel.: 030/3.43.41.
Instrumentation.
G 4; N 10.

NUCLEAIRE SERVICE MIJ. N.V., P.O. Box 194, The Hague. Tel.: 39.76.83.
Radioactive waste disposal, transportation of irradiated fuel elements, health physics consultation, laboratory design.
H 6, 7; L 2, 10, 13.

N.V. PHILIPS' GLOEILAMPENFABRIEKEN, Eindhoven. Tel.: K 4900 60.000. T.A.: Philips Eindhoven.
Electronic instrumentation.
G 1, 3, 4, 9; M 1, 2, 6, 10; N 1, 2, 3, 4, 5, 6, 7, 8, 10; P 1, 2, 3.

N.V. PHILIPS-DUPHAR, Apolloiaan 151, Amsterdam-Z. Tel.: 731226. T.A.: Vitamine Amsterdam.
Cyclotron and pile-produced radioisotopes.
L 2, 3; P 1, 2, 3.

PIELKENROOD-VINITEX N.V., Industrieweg, Assendelft. Tel.: 02980–83151.
Patented fume cupboards; lining with rigid pvc of laboratory tables, etc., exhaust installations made from rigid pvc.
Exhaust installation for Instituut voor Kernfysisch Onderzoek, Amsterdam; lining of lab. tables for Kernlaboratorium der Kema, Arnhem; fume cupboards for Instituut TNO, Utrecht; exhaust installation for Rijksverdedigingsorganisatie TNO, Rijswijk.
H 3; N 10.

N.V. DE PLAATWELLERIJ, P.O. Box 55, Beverwijk. Tel.: 02510–4941.
Chemical and processing equipment.
Hard rubber-lined transport vessels for radioactive waste and stirrers for RCN, Petten.
E 6; 9.

RONTGEN TECHNISCHE DIENST N.V., RTD, Delftweg 144, Rotterdam 8. Tel.: 82995. T.A.: Staaltest.
Non-destructive testing equipment.
L 3, 5; N 8; P 2.

DE ROTTERDAMSCHE DROOGDOK MIJ. N.V., P.O. Box 913, Rotterdam. Tel.: 010/176920. T.A.: Dockyard. Telex: 22181.
Boiler manufacture; pressure vessels and apparatus for the oil industry; heavy forgings.
Core structure for reactor pressure vessel for General Electric SENN plant, Italy; main equipment air lock for 20 MW high flux reactor, Petten; test pressure vessel for Neptunus project (testing of components for nuclear installations for Technical University, Delft, Royal Dutch Navy and Neratoom).
D 1, 2, 3, 4; E 3, 4, 6, 7, 8, 9; F 1, 2, 3; M 8, 9.

MACHINEFABR. THOLE N.V., Tollensstraat 20, P.O. Box 30, Enschede. Tel.: 3246. T.A.: Thole Enschede.
Overhead travelling cranes and slewing cranes for Petten, RCN.

VETTEWINKEL—PAINT AND VARNISH MANUFACTURERS, 79-82 Prins Hendrikkade, Amsterdam-C. Tel.: 12.38.54. T.A.: Paint Amsterdam.
Colturiet coatings (protective radiation-resistant coatings for the nuclear industry).
Coatings for walls and ceilings for laboratories at Petten, RCN.
L 10.

DE VRIES ROBBE & CO. N.V., P.O. Box 32, Gorinchem. Tel.: 01830–2541. T.A.: Vriesrobbe. Telex: 21699.
Steel structures, storage tanks, low pressure vessels.
E 4.

DOK- EN WERF-MIJ. WILTON-FIJENOORD N.V., Vlaardingerdijk, Schiedam Tel.: 69200. T.A.: Wilton Schiedam.
Pressure vessels, heavy and large machining.
Five fission product delay units to Dragon project, Winfrith.
D 1, 2; E 3, 4, 5, 8, 9; F 1, 2, 3; 14; L 13.

ZUID-HOLLANDSCHE PLETTERIJEN v/h D. A. HAMBURGER N.V., P.O. Box 19, Delft. Tel.: 22338. T.A.: Loodpletterij.
Manufacture and export of lead products.
Various lead shielding material to the Reactor Institute, Delft; lead bricks and other lead shielding material for several Dutch universities, hospitals and laboratories.
E 5; K 15; L 3, 4, 5.

NORWAY

KONGSBERG VAPENFABRIKK, Kongsberg. Tel.: Kongsberg 37. T.A.: Vapenfabrikken.
Remote control equipment.
Control drive and control rod for Noratom A/S, and IFA (Institute for Atomic Energy) Norway.
G 6, 7.

A/S KVÆRNER BRUG, Kværnerveien 10, Oslo. Tel.: 68.18.10. T.A.: Kværner. Telex: 1650.
Boiler manufacture, general fabrication.
Pressure vessel for HWBR (IFA).
E 3, 4.

NORATOM A/S, Holmenveien 20, Vinderen, Oslo. Tel.: 60.88.80. T.A.: Noratom.
(Joint stock company of the main industrial, commercial and shipping companies of Norway).
Planning, design, component production in the atomic energy field.
All main components, including instrumentation for Nora research reactor, Institutt for Atomenergi; complete isotope production and waste storage equipment for radioisotope production laboratory, United Arab Republic Atomic Energy Establishment, Cairo; fuel handling equipment for Halden BWR; waste treatment equipment for Institutt for Atomenergi.
A 3; C 1, 3; D 4; E 3, 4, 9; F 1, 2, 3, 5, 14; G 1, 6, 7, 9; H 1, 2, 3, 4, 6, 7; J 4; K 2, 10, 15; L 1, 2, 3, 4, 11, 12, 13; M 3, 4, 6, 8, 9, 10, 11; N 1, 2; P 1, 2.

INGENIORFIRMAET THEODOR QVILLER A/S, Stenersgaten 8, Oslo. Tel.: 421089. T.A.: Propeller.
Air conditioning, ventilation plants and equipment, filtration units.
F 1, 3; H 3, 4.

STANDARD TELEFON OG KABELFABRIK A/S, Box 60, Okern. Tel.: 67.74.80. T.A.: Microphone Oslo. Telex: 1485.
Radiation detectors and survey meters.
N 2, 3.

PORTUGAL

COMPANHIA, PORTUGUESA DE INDUSTRIAS NUCLEARES, CPIN, Av. Da Republica, 44-4°, Lisbon. Tel.: 763084. T.A.: Reactores.
Nuclear consultants and architects.

SWEDEN

ASEA GROUP (ALLMANNA AVENSKA ELEKTRISKA AB.) Vasteras. Tel.: 10.000. T.A.: Västeras.
Complete reactor engineering.
Extensive fabrication work for Agesta; design and development for Marviken and AKK project.

AKTIEBOLAGET ATOMENERGI, Lovholmsvagen 7, Box 9042, Stockholm 9. Tel.: 19.02.60. T.A.: Aterg Stockholm. Telex: 19.003.
Nuclear research; development of power reactors, etc., including fuel element production.
Second fuel element core for Halden BHWR, Institutt for Atomenergi, Norway; first fuel element core for Agesta.
C 1, 2, 3; P 2, 3.

AB SVENSKA FLAKTFABRIKEN, P.O. Box 20040, Stockholm 20. Tel.: 23.83.20. T.A.: Flaktfabriken. Telex: 1340.
Ventilation plant for RS laboratory, Studsvik, Sweden, cooling equipment for test loops Häxan and Ebba, Studsvik, Sweden, for AB Atomenergi; iodine washer for BER, Berlin, Hahn-Meithner Institute for Nuclear Research; ventilation plant for active laboratory, the Research Institute of the National Swedish Defence.
F 1, 11, 12, 14; H 3, 4.

AB GOTAVERKEN, Box 885, Goteborg 8. Tel.: 235480. T.A.: Götaverken.
Heat exchangers.
Electrical heater in pressurizing system for R3/Adam.
F 14.

JONKOPINGS MEKANISKA WERKSTADS AB, Jonkoping. Tel.: 19100. T.A.: Werkstaden.
Boilers, recovery units, centrifugal pumps.
Two heavy water/light water primary heat exchangers under construction for delivery June-July 1961, for R3/Adam Reactor Plant, Agesta.
F 14.

NORDISKA VARME AB, Goteborgsvagen 52, Box 5140, Goteborg 5. Tel.: 031/27.50.40. T.A.: Värmebolaget Göteborg.
Pipework and design.
Pipework for Kungl. Vattenfallsstyrelsen and ASEA.
värmeverk (R3/Adam).
F 1, 2.

REDERIAKTIEBOLAGET NORDSTJERNAN ATOMKRAFTGRUPPEN, Nynashamn. Tel.: Nynäshamn 13261. T.A.: Johnsons Stockholm.
Architect-engineering service, stainless steel production, heavy plate fabrication, manufacture of steam generators and pipework.
Stainless steel, pipework, primary circuit and forgings for steam generators for R3/Adam, Agesta, ASEA; high pressure test loop for fuel elements for Studsvik Research Centre, AB Atomenergi.
B 3; D 1, 2, 3; E 4, 6, 7, 8, 9; F 1, 3, 4, 5, 6, 14; K 14, 15.

Sweden (contd.)

NYDQVIST AND HOLM AB, Trollhatten. Tel.: 180.00. T.A.: Nohab.
Electronic equipment, heavy plate work, machining, cast iron, forgings, annealing; atomic power equipment.
Loading machine for R3/Adam, Agesta; projecting the mechanical part of the R4/Eva, Marviken atomic power station; part constructor of the Eurochemic Fuel Reprocessing Plant at Mol, Belgium.
H 1.

THE SANDVIK STEELWORKS CO., LTD., Sandviken. Tel.: 54100. T.A.: Sandvikenswed.
Steel and tungsten carbide products.
Tubing for DR 3, Mol, Halden, Kjeller, R 1 and R 2, Agesta.
C 5; D 3, 5; E 8; F 3, 14; K 5.

UDDEHOLMS AB, Uddeholm. Tel.: Hagfors 11400. T.A.: Uddeholms Uddeholm.
Steel work (stainless and stainless clad steels, M.S. and l.a. pressure vessel steels); heavy pressure vessel fabrication.
Pressurizer vessel, expansion tank for R3, Adam, ASEA, Västeras; main heat exchanger components for Halden Reactor, Norway, AB Rosenblads Patenter, Stockholm; 2 steam accumulators for Ranstad Uranium Works, AB Atomenergi, Stockholm; reactor pressure vessel, heavy water storage vessel components for Studsvik.
E 4, 8, 9; F 14; K 14.

SWITZERLAND

AMF ATOMICS (A Division of American Machine Foundry Company), AMF Building, Route de Meyrin, Geneva. Tel.: 34.77.00. T.A.: Ammafoco Geneva. Telex: 22.416.
Research, training and test reactors; reactor refuelling equipment; power reactor design; remote handling equipment; manipulators; nuclear fuel; fuel processing equipment; isotope applications; shielding and radiation studies; reactor control systems.
A 1, 2, 3, 4, 6; G 6, 7; H 1, 6, 7; L 7, 8; M 8.

ATOMELECTRA, LTD., Beethovenstr. 48, Zurich. Tel.: 27.38.10. T.A.: Atomelektra Zurich.
Nuclear engineering consultants.
Preliminary engineering and planning for Kernkraftwerk, Lucens.

D. BONNARD AND A. GARDEL, Consultant Engineers, Lausanne, 10 av. de la Gare. Tel.: 021/22.06.21.
Consultants.
Engineering services for projected nuclear power plant at Lucens; environmental surveys of radioactivity; health physics organization and procedures; nuclear power plant safety; shielding design; site location, nuclear facility.

BUSS, LTD., Pratteln/Basle. Tel.: 061/81.54.41. T.A.: Bussag.
Chemical engineering.
Fabrication of equipment especially in the field of hydrofluoric acid.
E 3, 4, 9.

ATELIERS DES CHARMILLES S.A., 109 Route de Lyon, Geneva. Tel.: 022/33.26.50. T.A.: Hydroturbo Geneva. Telex: Hydroturbo 22572.
Canned motor pumps; refuelling machinery; remote handling equipment.
Fuel charge/discharge machine (in conjunction with S.A. des Ateliers de Sécheron, Geneva) for Dragon, Winfrith.
F 7; H 1; L 8.

CORNING GLASS INTERNATIONAL S.A., Claridenstr. 22, Zurich.
Glass specialists.
Glass bricks, preassembled windows up to 2 m thick.

DEMIERRE ET CIE S.A., 5 Corraterie, Geneva. Tel.: 24.52.66. T.A.: Demierracier Geneva. Telex: 22372.
Zr and Zr alloys, wrought, semi- and finished products from Reactive Metals Inc.
Kollmorgan periscope for hot cell, hot laboratory in Würenlingen (Switzerland), Swiss Federal Institute for Reactor Researches.
C 1, 2; D 5; E 8; K 5; L 11.

ELECTRO-WATT, ELECTRICAL AND INDUSTRIAL MANAGEMENT CO., LTD., Talacker 16, Zurich. Tel.: 23.76.40. T.A.: Elektro-Watt Zurich.
Engineering and construction supervision of power plants and other civil works.
Preliminary engineering and planning for Kernkraftwerk, Lucens.

GEORGE FISCHER, LTD., Muhlentalstr. 105, Schaffhausen. Tel.: 053/5.60.31. T.A.: Geofischer Schaffhausen. Telex: 5.29.15 Geofischer Schf.
High quality electric steel castings.
Steam turbine cylinders, valve chest for Trawsfynydd, Richardsons Westgarth, Ltd., Hartlepool; steam turbine cylinder for Tokai Mura (Japan Atomic Power Co.), General Electric Co., Ltd., Erith; Stainless pump impeller and spiral casing for heavy water reactor, Klein, Schanzlin and Becker, Frankenthal; cast magnet plates for bubble chamber magnet, CERN, Oerlikon Engineering Co., Zurich; blower spiral casing for high temperature gas cooled reactor AVR, Brown, Boveri and Co., Ltd., Baden.

LUEKON PAUL LUSCHER, Tauffelen, Be. Tel.: 032/7.35.45. T.A.: Luekon Taeuffelen.
Electro-thermal appliances.
Helium heaters for Reaktor AG, Würenlingen.

METTLER, ANALYTICAL AND PRECISION BALANCES, Pelikanstr. 19, Zurich. Tel.: 051/25.02.30. T.A.: Mettlerbalance.
Remote controlled analytical balances.
Type W8 to AWRE, Aldermaston; B5/11 to Tokai Mura, Japanese Atomic Research Centre; B5C1000/11 to Idaho Falls, U.S.A., General Electric.
L 8; M 10.

OERLIKON ENGINEERING COMPANY, Zurich 50, Affolternstr. 50. Tel.: 48.18.10. T.A.: Oerlik Zurich.
Electrical equipment.
Power supply for magnets, with electronic current regulation for CERN, Geneva; magnets for bubble chamber, quadrupole and bending magnets
F 11; G 9; M 1, 11.

SECHERON WORKS CO., LTD., P.O. Box, Geneva 21. Tel.: 022/32.67.50.
Electric machines and apparatus, welding equipment.
Components for Triga reactors (aluminium and steel parts for reactor structures, pneumatic system for isotope transfer, water purification), University of Vienna, General Atomic; charge/discharge machine for Dragon Project (in conjunction with Charmilles); various supplies for Swiss experimental nuclear power station, Lucens, NGA (Federal Authority).
D 3, 4; E 11; F 7; G 6; H 1.

SUISATOM AG, 3 Bahnhofplatz, Zurich. Tel.: 051/27.93.47. T.A.: Suisatom AG Zurich.
Design, construction and operation of nuclear power plants, particularly to gain technical and economic experience; personnel training; exchange of information with similar organizations in Switzerland and abroad.

P. VOGEL AND CIE, Veyrier pres Geneve. Tel.: 022/36.35.60.
Manufacture of hot laboratory handling equipment; lead and aluminium transport flasks, remote handling tongs, pipettes and metering vessels.
L 6, 13.

CLASSIFIED SECTION

A RESEARCH REACTORS

1 Light water pool

BELGIUM
BelgoNucléaire.
FRANCE
Indatom.
GERMANY
Gutehoffnungshütte Sterkrade AG.
Siemens-Schuckertwerke AG.
Dr. Virus Kerntecknik.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
Machinefabriek " Breda."
N.V. Neratoom.
SWITZERLAND
AMF Atomics.

2 Light water tank

FRANCE
Indatom.
GERMANY
Deutsche Delattre & Levivier.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
Machinefabriek " Breda."
N.V. Neratoom.
SWITZERLAND
AMF Atomics.

3 Heavy water

NORWAY
Noratom.
NETHERLANDS
Machinefabriek " Breda."
N.V. Neratoom.
SWITZERLAND
AMF Atomics.

4 Argonaut type

GERMANY
AEG.
Siemens-Schuckertwerke AG.
NETHERLANDS
Koopman & Co.
SWITZERLAND
AMF Atomics.

5 Solution type

GERMANY
Interatom.

6 Graphite

FRANCE
Pechiney.
Ugine.
SWITZERLAND
AMF Atomics.

B POWER REACTORS

1 Graphite

FRANCE
Ste. Alsthom.
GAAA.
Indatom.
Pechiney.
Ugine.
GERMANY
Gutehoffnungshütte Sterkrade AG.
Interatom.
Sigri-Kohlefabrikate GmbH.

2 Heavy water

BELGIUM
BelgoNucléaire.
FRANCE
GAAA.
Indatom.
GERMANY
Interatom.
Siemens-Schuckertwerke AG.
NETHERLANDS
N.V. Neratoom.

3 PWR

BELGIUM
ACEC.
FRANCE
Ste. Alsthom.
Indatom.
GERMANY
Siemens-Schuckertwerke AG.
NETHERLANDS
N.V. Neratoom.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.

4 BWR

BELGIUM
BelgoNucléaire.
FRANCE
Ste. Alsthom.
Indatom.
Ste. Rateau.
GERMANY
AEG.
NETHERLANDS
N.V. Neratoom.

5 Organic cooled

FRANCE
GAAA.
Indatom.
Ugine.
GERMANY
Interatom.

C FUEL ELEMENTS

1 Complete elements

AUSTRIA
Austro-Chematom Kernbrennstoff GmbH
BELGIUM
Métallurgie et Mécanique Nucléaires.
FRANCE
Cie Industrielle des Combustibles Atomiques Frittes.
Ste. Industrielle de Combustible Nucleaire.
GERMANY
NUKEM.
Sigri-Kohlefabrikate GmbH.
NORWAY
Noratom.
SWEDEN
AB Atomenergi.
SWITZERLAND
Demierre et Cie S.A.

2 Uranium rods

BELGIUM
Métallurgie et Mécanique Nucléaires.
GERMANY
NUKEM.
SWEDEN
AB Atomenergi.
SWITZERLAND
Demierre et Cei S.A.

Nuclear Engineering

DATA SHEET

No. 17. Magnesium Alloys

(excluding Magnox—see No. 16)

MAGNESIUM—ZIRCONIUM ALLOYS

COMPOSITION

ZA alloy Mg—0·45–0·65% Zr
ZA–Be alloy Mg—0·62% Zr–0·002% Be

THERMAL NEUTRON CAPTURE CROSS SECTION

ZA 0·00256 cm^2/cm^3 [2]

COEFFICIENT OF LINEAR THERMAL EXPANSION (α)

Extruded ZA[4]

Temperature (°C)	18–100	18–200	18–300	18–400
$\alpha \times 10^6$/°C	25·7	26·4	27·0	27·7

RECRYSTALLIZATION AND GRAIN GROWTH

TABLE 1

Critical Strain Data from ZA Tapered Tensile Specimens [3]

Extruded Bar Pre-annealed—500°C for 30 min.
Original grain size $1–2 \times 10^{-3}$ in

Pre-straining temp., °C	Annealing		Critical strain, %	Peak grain size, in
	Temp., °C	Time, h		
R.T.	500	1	—*	—
R.T.	500	16	1½	—
R.T.	500	100	3	—
200	500	1	5	25×10^{-3}
200	500	16	4½	28
200	500	100	4	30
300	500	1	5½	18
300	500	16	6	20
300	500	100	5	22
500	500	1	—*	—
500	500	16	—*	—
500	500	100	—*	—
500	500	1 000	10	15

* No critical strain effect.

TABLE 2

Critical Strain Effects in ZA, ZA–Be Alloy [3]

Tapered tensile specimens of the alloys in the as-extruded state were pre-strained rapidly at 250°C and annealed as indicated

Annealing treatment		ZA strip		ZA–Be bar	
Temp., °C	Time, h	Critical strain, %	Peak grain size, 10^{-3} in	Critical strain, %	Peak grain size, 10^{-3} in
400	1	18·5	9	—	—
400	16	11	6·5	15	3
400	100	25·5	3	10	7
450	1	5·5	6	—	—
450	16	8	12	7	6
450	100	11	8·7	5	8
500	1	3	15	8	6
500	16	4·5	16	5	7
500	100	3	15	5	11

MECHANICAL PROPERTIES

TABLE 3

Elastic Moduli [3]

Temperature, °C	20	50	100	150	200	250	300	350	400	450
Modulus of Rigidity† n ($lb/in^2 \times 10^{-6}$)	2·28	2·26	2·19	2·11	2·01	1·91	1·80	1·68	1·55	1·40
Young's Modulus* E ($lb/in^2 \times 10^{-6}$) ..	6·13	6·04	5·86	5·63	5·38	5·10	4·83	4·53	4·20	3·80

† n determined by torsional oscillation method; frequency of oscillation 2–3 c/s.
* E calculated from n assuming Poisson's ratio 0·33.

TABLE 4

Tensile Properties of ZA Heat-treated at 500°C for 4 hours [3]

Strain-Rate—1 075%/h

Test temp. °C	L.O.P. ton/in²	U.T.S. ton/in²	Elong. %	R. of A. %
RT	9·6	14·0	11	8
RT	8·2	12·7	6	5
50	10·2	14·6	14	15
50	6·6	9·2	10	9
100	7·2	9·4	26	20
100	6·0	9·0	15	16
150	5·4	7·4	36	30
200	3·5	5·0	68	60
200	2·9	4·9	56	68
250	2·6	4·8	62	68
300	1·9	3·2	76	88
350	1·2	2·3	122	96
400	0·74	1·24	142	>99
450	0·44	0·51	186	>99

TABLE 5

Ductility of ZA at slow strain rates [4]

Strain rate % / h	Elongation % at fracture					
	Testing temperature					
	20°C	100°C	200°C	300°C	400°C	500°C
1	20	74	77	106	132	55*
0·1			76		218	

* Mean value of two or more tests.

TABLE 7

Stress-rupture Data for Extru

Grain size 0·001–0·003

Temp. °C	Stress ton/in²	Time in hours for specified % creep strain					
		1%	2%	5%	10%	15%	20%
Heat-Treated (200°C for 20 min followed by 450°C for 2 h)							
200	1	200	690	3 225	6 540	7 040	
200	0·8	473	820	1 500	2 450	2 960	
200	1·25	30	140	630	1 360	1 800	2 075
200	1·5	1	2·5	11·5	29	51	74
200	1·75						
250	0·4	209	526*				
250	0·8	3	10	26	53	75	92*
250	1	0·5	2	6	13	20	25
300	0·3	13	33	102	231	356	
300	0·4	2	8	26			
350	0·16	14	29	90	208	356	515
350	0·2	4	11	43	142	252	341
350	0·3	3	8	25	55	79	
350	0·35	0·8	1·8	5·5	12	19	23
400	0·1	9	20	70	180	322	495
400	0·11	9	20	65	163	287	400
400	0·16	5	9	20	42	64	88
400	0·16	4	8	23	50	68	
400	0·16	2·5	5	13	26	40	50
400	0·2	1·3	2·6	6·9	14	22	
400	0·28	0·3	0·6	1·6	3	4·3	5.4
450	0·1	4	6	13	29	52	75
As-extruded							
200	1·25	3·5	9	46	101	146	188
200	1·25	3	10	57	139	200	248
200	1·25	3	12	62	138	197	
200	1·75						
200	1·75	0·3	0·7	2·2			
400	0·16	4	9	30	85	165	280

All tests carried out in air.
* Test discontinued.
† Specimen became oxidized d

LE 4
-treated at 500°C for 4 hours (³)
—1 075%/h

T.S. /in²	Elong. %	R. of A. %
0	11	8
7	6	5
6	14	15
2	10	9
4	26	20
0	15	16
4	36	30
0	68	60
9	56	68
8	62	68
2	76	88
3	122	96
24	142	>99
51	186	>99

LE 5
slow strain rates (⁴)

ngation % at fracture				
esting temperature				
200°C	300°C	400°C	500°C
77 76	106	132 218	55*

TABLE 6
Stress rupture data for Impact Extruded, 0·060 in thick ZA strip, pre-annealed 500°C for 30 min (⁵)

Test temp. °C	Stress ton/in²	Time to failure h	Minimum creep rates in/in h	Elongation % (gauge length 5 in)	Reduction of area %
175	3·0	7	—	71	66
	1·5	1 040	$2{\cdot}9 \times 10^{-4}$	60	56
200	2·0	6	—	58	59
	1·5	44	—	48	70
	1·45	54	$4{\cdot}66 \times 10^{-3}$	48	70
	1·25	152	$7{\cdot}28 \times 10^{-4}$	59	72
	1·25	260	$6{\cdot}76 \times 10^{-4}$	46	73
	1·0	1 138	$1{\cdot}4 \times 10^{-4}$	77	78
	0·75	3 014	$1{\cdot}6 \times 10^{-5}$	46	73
225	0·5	3 140	$3{\cdot}8 \times 10^{-5}$	38	79
300	1·0	1¼	—	93	85
	0·5	4 914	$<4{\cdot}5 \times 10^{-5}$	66	68
400	0·11	190	$3{\cdot}97 \times 10^{-3}$	132	—
	0·09	607	$1{\cdot}1 \times 10^{-3}$	102	—
	0·075	1 680	$6{\cdot}3 \times 10^{-4}$	134	91
425	0·077	571	—	134	89
	0·069	727	—	123	>99
450	0·09	140	—	82	—
	0·07	772	$6{\cdot}78 \times 10^{-4}$	88	—
475	0·062	420	$6{\cdot}94 \times 10^{-4}$	72	89
	0·055	1 475	$2{\cdot}88 \times 10^{-4}$	87	90
500	0·055	1 232	$2{\cdot}17 \times 10^{-4}$	61	88

Tests: 175–300°C in air and 400–500°C in CO_2.

TABLE 7
Stress-rupture Data for Extruded ZA Bar
Grain size 0·001–0·003 in(⁸)

Time in hours for specified % creep strain						Total creep strain at fracture %	Time to rupture h	Min. creep rate, in/in h
5%	10%	15%	20%	25%	30%			
by 450°C for 2 h)								
3 225	6 540	7 040				67	7 171	$1{\cdot}14 \times 10^{-5}$
1 500	2 450	2 960				60·2	4 216	$1{\cdot}03 \times 10^{-3}$
630	1 360	1 800	2 075	2 260	2·395	38·2	2 520	$5{\cdot}56 \times 10^{-3}$
11·5	29	51	74			36	146	$2{\cdot}2 \times 10^{-3}$
						61·3	27	—
						—	—	$1{\cdot}85 \times 10^{-5}$
26	53	75	92*			80	153	$1{\cdot}74 \times 10^{-3}$
6	13	20	25			97·5	57	$7{\cdot}29 \times 10^{-3}$
102	231	356				46	544	$3{\cdot}75 \times 10^{-4}$
26						64·2	134	$1{\cdot}5 \times 10^{-3}$
90	208	356	515	650		119·2	1 500	$3{\cdot}21 \times 10^{-4}$
43	142	252	341			56	574	$4{\cdot}29 \times 10^{-4}$
25	55	79				35	196	$1{\cdot}47 \times 10^{-3}$
5·5	12	19	23	27	30	106·8	46	$8{\cdot}2 \times 10^{-3}$
70	180	322	495	680		70*	3 750	$2{\cdot}98 \times 10^{-4}$
65	163	287	400	497	582	98	995	$4{\cdot}07 \times 10^{-4}$
20	42	64	88	110	129	102	227	$2{\cdot}13 \times 10^{-3}$
23	50	68				66	154	$2{\cdot}0 \times 10^{-3}$
13	26	40	50			83	87	$4{\cdot}0 \times 10^{-3}$
6·9	14	22				90·8	64±8	$6{\cdot}75 \times 10^{-3}$
1·6	3	4·3	5·6			94	14±8	$3{\cdot}1 \times 10^{-3}$
13	29	52	75	105		82†	596	$2{\cdot}02 \times 10^{-3}$
46	101	146	188	223		73	351	$8{\cdot}25 \times 10^{-4}$
57	139	200	248	291		73·6	455	$6{\cdot}0 \times 10^{-4}$
62	138	197				53·6	424	$5{\cdot}72 \times 10^{-4}$
						66	42	—
2·2						40·6	24	$1{\cdot}17 \times 10^{-3}$
30	85	165	280	393	492	125·2	720	$4{\cdot}0 \times 10^{-4}$

All tests carried out in air.
* Test discontinued.
† Specimen became oxidized during test.

Influence of Grai

Condition	Mn content %	Mean gra dia., in
As-extruded	0·99	0·005
Solution-treated 565°C for 4h	0·77 0·73	0·012 Very coar
	0·77 0·73	0·012 Very coar
	0·77 0·73	0·012 Very coar
	0·77 0·73	0·012 Very coar

* Equivalent to percentage strain
† Ruptured.

Effect of Manganese Co

Condition	Mean grain dia., in	Mangane content %
As-extruded	0·019	1·49
Solution-treated	0·026	1·49
	0·012	0·77
	0·028	0·25

* Equivalent to percentage strain
† Ruptured.
‡ These creep curves exhibited i

MAGNESIUM-MANGANESE ALLOYS

COMPOSITION

AM503S Mg–0·5–1·0w/o Mn
AM503 Mg–1·5w/o Mn

PHYSICAL PROPERTIES

TABLE 1

Thermal Conductivity kcal/s °C(²)

	0°C	100°C	200°C	300°C
AM503S	0·352	0·355	0·357	0·360
Mg–2·64% Mn ..		0·336	0·34	

NUCLEAR PROPERTIES

Thermal neutron cross section—0·00520 cm²/cm³ (²)
Cross section relative to A.12 1·99 (²)

MECHANICAL PROPERTIES

TABLE 2

Influence of Grain Size on Tensile Properties of AM503S at 450°C at a Strain Rate of 790%/h(⁷)

Manganese content, %	Mean grain dia., in	Tensile strength, lb/in²	Elongation at fracture, %
0·77	0·012	1 366	84
0·73	Very coarse	1 098	84

TABLE 3

luence of Grain Size on Creep-resistance at 450°C of AM503S (⁷)

ln tent %	Mean grain dia., in	Creep results				
		Stress lb/in²	Creep strain at 1 000 h %	Minimum creep rate, in/in h ×10³*	Duration of test, h	Final elongation, %
99	0·005	100	1·76	1·0	2 952	5·30
77	0·012	100	1·72	1·6	1 824	2·95
73	Very coarse	100	0·01	0·01	1 000	0·01
77	0·012	224		6·0	730†	23·5†
73	Very coarse	224	0·143	0·04	5 344†	6·0†
77	0·012	280		8·5	327†	15·3†
73	Very coarse	280	0·20	0·10	3 416†	6·5†
77	0·012	380		196	51†	35·8†
73	Very coarse	380		22·5	379†	19†

rcentage strain per 1 000 h.

TABLE 4

Manganese Content on Creep-resistance at 450°C of Binary Magnesium-Manganese Alloys (⁷)

lean rain a., in	Manganese content, %	Creep results				
		Stress lb/in²	Creep Strain at 1 000 h %	Minimum creep rate, in/in h ×10³*	Duration of test, h	Final elongation, %
019	1·49	100	0·019	1 002	1 880	0·019
026	1·49	100	0·017	0·002‡	3 140	0·068
		224	0·125	0·025‡	3 170	0·78
012	0·77	100	1·72	1·6	1 824	2·95
		224		6·0	730†	23·5†
028	0·25	100	1·05	1·0	8 350	7·45
		224		250	113†	24†

ercentage strain per 1 000 h.

urves exhibited inflections: the minimum creep rates quoted were relatively short-lived.

Nuclear Engineering

DATA SHEET

No. 17 Magnesium Alloys

(excluding Magnox—see No. 16)

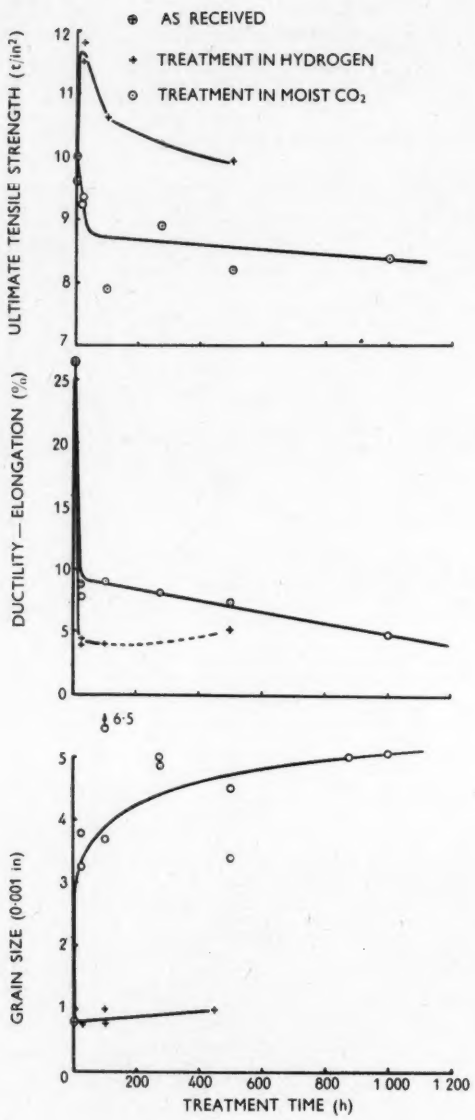
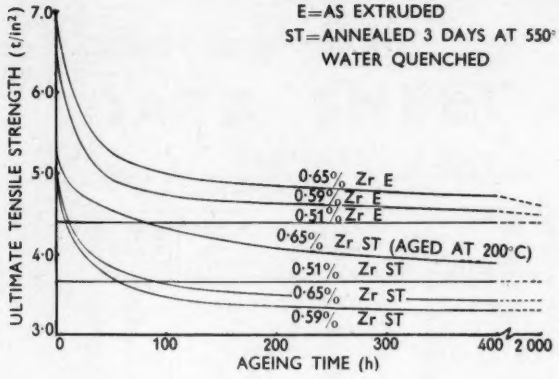


Fig. 1.—Changes in the room temperature tensile properties and grain size of ZA with time of treatment at 475°C in moist CO_2 and hydrogen (3).



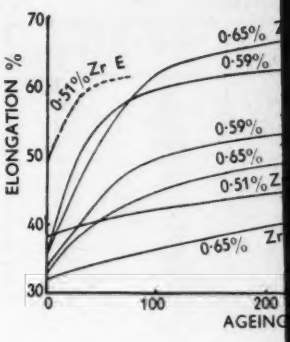


Fig. 2.—Effect of ageing at 200°C and 250°C on the tensile properties of ZA alloy at 20

MAGNESIUM-ZIRCONIUM-MANGANESE ALLOYS

COMPOSITION(7) (8) (9)

	Wt. % Zr	Wt. % Mn	
Magzan 1	0·18	0·11	Balance Mg.
Magzan 2	0·56	0·10	Balance Mg.
Magzan 3	0·19	0·32	Balance Mg.
Magzan 4	0·73	0·27	Balance Mg.

RECRYSTALLIZATION AND GRAIN GROWTH

TABLE 1

Critical Strain Effects in Magzan 2(3)

Tapered tensile specimens from the as-extruded material were pre-strained rapidly at 250° and annealed as indicated.

Annealing treatment		Magzan 2 Bar	
Temp., °C	Time, h	Critical strain, %	Peak grain size, in
400	1	—	—
400	16	—	—
400	100	10	·005
450	1	—	—
450	16	9	·0035
450	100	4	·003
500	1	4	·005
500	16	4½	·004
500	100	2	·007

TABLE 2

Grain Growth in Long-Time Anneals at 500°C(7)

Alloy	Mean grain dia., in		
	As-extruded	After 1 000 h	After 5 000 h
Magzan 1	0·0015	0·003	—
Magzan 2	0·001	0·0015	0·002
Magzan 3	0·001	0·003	—
Magzan 4	0·0015	0·003–0·060	—
Mg–0·16% Zr	0·0015	0·007	—
Mg–0·6% Zr	0·0015	0·004	0·014

MECHANICAL PROPERTIES

TABLE 3

Elongation (%) at Rupture with Slow Rates of Strain(7)

Alloy	200°C		400°C		500°C
	1%/h	0·1%/h	1%/h	0·1%/h	1%/h
Magzan 1	37	41	72	63	85
Magzan 2	49	41	120	59	94
Magzan 3	77	—	114	—	99
Magzan 4	85	—	96	—	87
Mg–0·16% Zr ..	77	54	99	135	141
Mg–0·6% Zr ..	77	76	132	218	55

TABLE

Creep Properties of As-Extruded

Alloy	Mean grain dia., in	Creep strain a 1 000 h %
Magzan 1	0·0015	0·06
Magzan 2	0·001	0·05
ZA (0·6% Zr) ..	0·0015	21·4†
Magnox A 12 ..	0·007	1·25
AM503S (0·99% Mn) ..	0·005	1·76
AM503 (1·49% Mn) ..	0·019	0·018

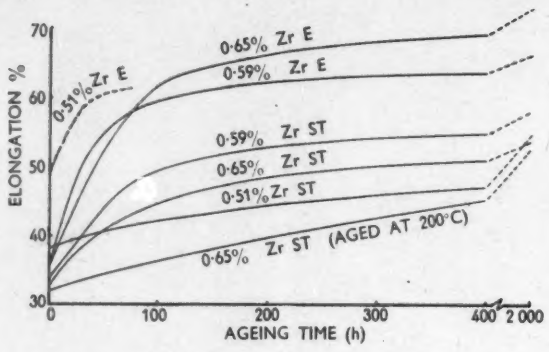
* Equivalent to percentage strain per 1 00
† Duplicate test gave similar results.

TABLE

Creep Properties at 500°C of As-

Alloy	Mean grain dia., in	Stress lb/in²	Cr strai 1 00 %
Magzan 3 ..	0·001	50	0·1
		100	1·0
Magzan 4 ..	0·0015	50	0·0
		100	0·0

* Equivalent to percentage strain per 1 00
† Duplicate test gave similar results.



°C on the tensile properties of ZA alloy at 200°C.

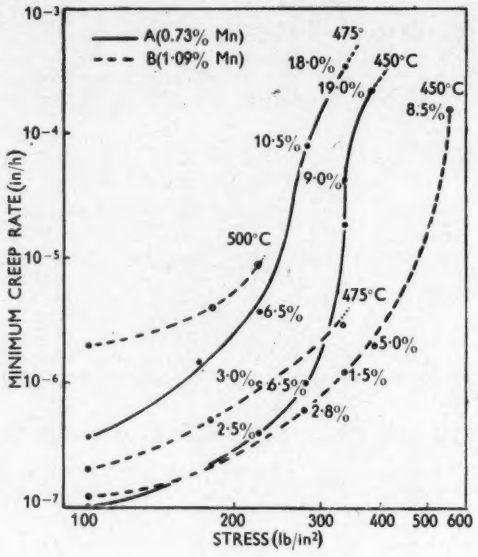


Fig. 3.—Creep resistance as a function of stress at 450-500°C for solution treated alloys containing 0·73 and 1·09% manganese (7). Percentages indicate elongation at rupture.

TABLE 4

Creep Properties of As-Extruded Alloys at 450°C and 100 lb/in²(7)

Alloy	Mean grain dia., in	Creep Results			
		Creep strain at 1 000 h, %	Minimum creep rate, in/in h ×10³*	Duration of test, h	Final elongation %
Magzan 1	0·0015	0·06	0·02	1 361	0·07
Magzan 2	0·001	0·05†	0·02†	1 000†	0·05†
ZA (0·6% Zr) ..	0·0015	21·4†	6·8†	1 303†	22·8†
Magnox A 12 ..	0·007	1·25	1·1	2 989	4·5
AM503S (0·99% Mn) ..	0·005	1·76	1·0	2 952	5·30
AM503 (1·49% Mn) ..	0·019	0·018	0·002	1 880	0·019

* Equivalent to percentage strain per 1 000 h.
† Duplicate test gave similar results.

TABLE 5

Creep Properties at 500°C of As-Extruded Magzan 3 and 4(7)

Alloy	Mean grain dia., in	Creep Results				
		Stress lb/in²	Creep strain at 1 000 h %	Minimum creep rate in/in h ×10³*	Duration of test, h	Final elongation %
Magzan 3 ..	0·001	50	0·13	0·09	2 105	0·23
		100	1·98	0·7	1 000†	1·08†
Magzan 4 ..	0·0015	50	0·07	0·04	1 000	0·07
		100	0·06†	0·03†	2 000†	0·10†

* Equivalent to percentage strain per 1 000 h.
† Duplicate test gave similar results.

AQUEOUS CORROSION OF MAGNESIUM ALLOYS(3)

The corrosion of both Magnox A12 and ZA alloy can be almost completely suppressed in water at pH 11·5 (200 ppm NaOH).

Chromates (50 ppm) are also effective in reducing corrosion.

A carbonaceous film formed by reaction with CO_2 at temperatures >450°C will accelerate corrosion especially when Cl ions are present in the water.

TABLE 1

Type of water	Temp. °C	Corrosion rate mg/dm²d			
		A12		ZA	
		Clean	With carbon	Clean	With carbon
Distilled	40	17	24	19	22
pH 11·5..	40	0·7	0·80	1·1	1·4
pH 11·5+5 ppm Cl' ..	40	0·3	2·2	0·4	3·8

Mg ALLOYS
REFERENCES

1. Brookes, P. E., *et al. J. Inst. Metals* 1959–60, **88**, 12, p. 500–508.
2. Heal, T. J. *Nucl. Energy* 3, 23, Feb., 1958, p. 52–61.
3. Reactor Materials Laboratories, U.K.AEA, Culcheth. Unpublished work.
4. Magnesium Data Manual, 1960. Printed and Published by U.K.AEA, Risley, Warrington, Lancs.
5. Fuel Element Development Directorate, U.K.AEA, Springfields. Unpublished work.
6. Olds, G. C. E., *et al.* Mechanical Properties of alloys of Magnesium and Zirconium. Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva (1958) 5, p. 259.
7. Olds, G. C. E. and Michie, G. M. Creep-resistant Magnesium Alloys for Nuclear Fuel Elements. *J. Inst. Metals* 1959–60 **88**, p. 493–499.
8. Olds, G. C. E. British Patent Specification, 851,871.
9. Whitehead, D. J. and Emley, E. F. British Patent Specification 806,104.

3 Ceramic pellets
BELGIUM
Métallurgie et Mécanique Nucléaires.
FRANCE
Cie Industrielle des Combustibles Atomiques Frittes.
CSF.
GERMANY
NUKEM.
NORWAY
Noratom.
SWEDEN
AB Atomenergi.

4 Cermets
FRANCE
CSF.
GERMANY
NUKEM.

5 Fuel cans
FRANCE
SNECMA.
Ste. Lorraine-Escaut.
GERMANY
Sigri-Kohlefabrikate GmbH.
SWEDEN
The Sandvik Steelworks Co. Ltd.

6 End caps
FRANCE
SNECMA.

7 Ceramic inserts
FRANCE
CSF.
GERMANY
NUKEM.

D CORE STRUCTURES

1 Heavy plate steel
AUSTRIA
Waagner-Biro AG.
BELGIUM
BelgoNucléaire.
Cockerill-Ougrée S.A.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
Ste. Lorraine-Escaut.
Ugine.
GERMANY
Deutsche Delattre & Levivier.
Kloeckner-Werke AG.
Phoenix-Rheinrohr AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
ITALY
Terni.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
Machinefabriek " Breda."
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.

2 Heavy s.s. members
AUSTRIA
Waagner-Biro AG.
BELGIUM
ACEC.
BelgoNucléaire.
Cockerill-Ougrée S.A.
FRANCE
Compagnie des Ateliers et Forges de la Loire
Ste. des Forges et Ateliers du Creusot.
GERMANY
Deutsche Delattre & Levivier.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
Machinefabriek " Breda."
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.

3 Precision steel
AUSTRIA
Waagner-Biro AG.
BELGIUM
BelgoNucléaire.
Cockerill-Ougrée S.A.
FRANCE
Compagnie des Ateliers et Forges de la Loire
Ste. des Forges et Ateliers du Creusot.
Ste. Lorraine-Escaut.
Ugine
GERMANY
Phoenix-Rheinrohr AG.
Rochling'sche Eisen- u. Stahlwerke GmbH.
Kloeckner-Werke AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.
The Sandvik Steelworks Co. Ltd.
SWITZERLAND
Secheron Works Co. Ltd.

4 Light alloy structures
AUSTRIA
Waagner-Biro AG.
BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Compagnie des Ateliers et Forges de la Loire
Tréfileries et Laminoirs du Havre.
Ugine.
GERMANY
Deutsche Delattre & Levivier.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
NORWAY
Noratom.
SWITZERLAND
Secheron Works Co., Ltd.

5 Zr and Zr alloy parts
FRANCE
CSF.
Péchiney.
Tréfileries et Laminoirs du Havre.
Ugine.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
SWEDEN
The Sandvik Steelworks Co. Ltd.
SWITZERLAND
Demierre et Cie S.A.

6 Be parts
FRANCE
Péchiney.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.

7 Machined graphite
FRANCE
Ste. des Forges et Ateliers du Creusot.
Péchiney.
Ugine.
GERMANY
Sigri-Kohlefabrikate GmbH.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.

E REACTOR VESSELS

1 Concrete vessels
GERMANY
Hochtief AG.

2 Pre-stressing cables
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. Lorraine-Escaut.

3 Light alloy tanks
AUSTRIA
Waagner-Biro AG.
BELGIUM
ACEC.
BelgoNucléaire.
DENMARK
A/S Burmeister and Wain's Maskin- og Skibsbyggeri.
GERMANY
Deutsche Delattre & Levivier.
Gutehoffnungshütte Sterkrade AG.
Kloeckner-Werke AG.
Phoenix-Rheinrohr AG.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Bronswerk.
" Isola " N.V.
" Jaro."
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
A/S Kværner Brug.
SWITZERLAND
Buss, Ltd.

4 M.S. and l.a. steel vessels
AUSTRIA
Waagner-Biro AG.
BELGIUM
BelgoNucléaire.
Cockerill-Ougrée S.A.
FRANCE
Ste. Alsthom.
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
GAAA.
Ste. Lorraine-Escaut.
GERMANY
Deutsche Delattre & Levivier.
Gutehoffnungshütte Sterkrade AG.
Henschel-Werke GmbH.
Kloeckner-Werke AG
Phoenix-Rheinrohr AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
ITALY
Breda Termomeccanica.
Brescia.
Terni.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
Machinefabriek " Breda."
N.V. Bronswerk.
" Jaro."
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
De Vries Robbe and Co., N.V.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
A/S Kværner Brug.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.
SWITZERLAND
Buss, Ltd.

5 Lead lined tanks
BELGIUM
BelgoNucléaire.
GERMANY
Deutsche Delattre & Levivier.
Henschel-Werke GmbH.
Stolberger Zink AG.
ITALY
Breda Termomeccanica.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
Machinefabriek " Breda."
Wilton-Fijenoord N.V.
Zuid-Hollandsche Pletterijen.

6 Nozzles
AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
Cockerill-Ougrée.
GERMANY
Deutsche Delattre & Levivier.
Hartmann and Braun AG.
ITALY
Breda Termomeccanica.
Brescia.
Terni.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Bronswerk.
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
N.V. De Plaatwellerij.
De Rotterdamsche Droogdok Mij., N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.

7 Standpipes
AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. Lorraine-Escaut.
GERMANY
Deutsche Delattre & Levivier.
Phoenix-Rheinrohr AG.
ITALY
Breda Termomeccanica.
Dalmine SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Bronswerk.
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.

8 Pressure tubes
AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
Belchim.
BelgoNucléaire.
Cockerill-Ougrée S.A.
FRANCE
Ste. Lorraine-Escaut
Ugine.
GERMANY
Deutsche Delattre & Levivier.
Phoenix-Rheinrohr AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
ITALY
Breda Termomeccanica.
Dalmine SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.
The Sandvik Steelworks Co., Ltd.
Uddeholms AB.

SWITZERLAND
Demierre et Cie S.A.

9 Stainless steel vessels

AUSTRIA
Waagner-Biro AG.
BELGIUM
Belchim.
BelgoNucléaire.
Cockerill-Ougrée S.A.
Nouveaux Ateliers Lebrun.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
Ste. Rateau.
GERMANY
Deutsche Delattre & Levivier.
Gutehoffnungshütte Sterkrade AG.
Henschel-Werke GmbH.
Kloeckner-Werke AG.
Phoenix-Rheinrohr AG.
ITALY
Breda Termomeccanica.
Terni.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
N.V. Machinefabriek " Arnhem."
Machinefabriek " Breda."
N.V. Bronswerk.
" Jaro."
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
N.V. De Plaatwellerij.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraft-gruppen.
Uddeholms AB.
SWITZERLAND
Buss, Ltd.

10 Special cutting equip.

FRANCE
Siersatom.
GERMANY
Deutsche Delattre & Levivier.
NETHERLANDS
N.V. Neratoom.

11 Special welding equip.

FRANCE
Siersatom.
GERMANY
Deutsche Delattre & Levivier.
NETHERLANDS
N.V. Neratoom.
SWITZERLAND
Sécheron Works Co., Ltd.

12 Corrosion protection

AUSTRIA
Waagner-Biro AG.
BELGIUM
Ste. d'Arendonk.
FRANCE
Ste. Alsthom.
Compagnie des Ateliers et Forges de la Loire
Compagnie Lyonnaise de Génie Chimique P. Lacollonge.
GERMANY
Gewerkschaft Keramchemie.
Kloeckner-Werke AG.
Phoenix-Rheinrohr AG.
Stolberger Zink AG.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
Chamotte Unie N.V.
" Isola " N.V.

13 Thermal insulation

DENMARK
A/S Hasle Klinker-og Chamottestensfabrik.
FRANCE
Siersatom.
GERMANY
Deutsche Delattre & Levivier.
Kloeckner-Werke AG.
ITALY
Breda Termomeccanica.
Riva and Mariani.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Isola " N.V.

F PRIMARY COOLANT CIRCUITS

1 M.S. duct and pipework

AUSTRIA
Waagner-Biro AG.
BELGIUM
Ste. d'Arendonk.
BelgoNucléaire.
S.A. Carnoy-Vandensteen.
Cockerill-Ougrée S.A.
Nouveaux Ateliers Lebrun.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
GAAA.
Ste. Lorraine-Escaut.
GERMANY
Deutsche Delattre & Levivier.
Gutehoffnungshütte Sterkrade AG.
Phoenix-Rheinrohr AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
ITALY
Breda Termomeccanica.
Brescia.
Dalmine SpA.
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
Machinefabriek " Breda."
N.V. Bronswerk.
" Jaro."
N.V. Leidsche Apparantenfabriek.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
Theodor Qviller A/S.
SWEDEN
AB Svenska Flaktfabriken.
Nordiska Värme AB
Rederiaktiebolaget Nordstjernan Atomkraft-gruppen.

2 L.a. steel pipework

AUSTRIA
Waagner-Biro AG.
BELGIUM
BelgoNucléaire.
S.A. Carnoy-Vandensteen.
Cockerill-Ougrée S.A.
Nouveaux Ateliers Lebrun.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
GAAA.
Ste. Lorraine-Escaut.
GERMANY
Deutsche Delattre & Levivier.
Gutehoffnungshütte Sterkrade AG.
Phoenix-Rheinrohr AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
ITALY
Breda Termomeccanica.
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
Machinefabriek " Breda."
N.V. Bronswerk.
" Jaro."
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
SWEDEN
Nordiska Värme AB.

3 S.S. tubing

AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
BelgoNucléaire.
S.A. Carnoy-Vandensteen.
Cockerill-Ougrée S.A.
Nouveaux Ateliers Lebrun.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
GAAA.
Ste. Lorraine-Escaut.
Ugine.
GERMANY
Emil Helfferich Nachfolger.
Phoenix-Rheinrohr AG.
ITALY
Dalmine SpA.
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
Machinefabriek " Breda."
N.V. Bronswerk.
" Jaro."
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
De Rotterdamsche Droogdok Mij., N.V.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
Theodor Qviller.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraft-gruppen.
The Sandvik Steelworks Co. Ltd.

4 Expansion joints

AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
BelgoNucléaire.
GERMANY
Deutsche Delattre & Levivier.
ITALY
Breda Termomeccanica.
Terni.
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Bronswerk.
" Jaro."
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraft-gruppen.

5 High pressure water valves

AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
ACEC.
Cockerill-Ougrée S.A.
FRANCE
Ste. Rateau.
ITALY
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
G. Dikkers and Co. N.V.
W. C. t'Hart and Zn.
" Jaro."
NORWAY
Noratom.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraft-gruppen.

6 Other water valves

AUSTRIA
Waagner-Biro AG.
BELGIUM
Anbuma S.A.
BelgoNucléaire.
FRANCE
GAAA.
MacGregor Comarain S.A.
Siersatom.
Ste. Rateau.
GERMANY
Deutsche Delattre & Levivier.
ITALY
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
G. Dikkers and Co. N.V.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraft-gruppen.

7 Submersible pumps

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
CSF.
Pompes Ratier.
Ste. Rateau.
ITALY
Franco Tosi SpA.
NETHERLANDS
" Aquapur."
N.V. Neratoom.
SWITZERLAND
Ateliers de Charmilles S.A.
Sécheron Works Co., Ltd.

8 Other reactor pumps

BELGIUM
ACEC.
FRANCE
CSF.
Ste. Rateau.
ITALY
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."

9 Liquid metal pumps

FRANCE
GAAA.
Ste. Rateau.
GERMANY
Walbersdorf Sondermaschinenbau.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.

10 Liquid metal valves

FRANCE
GAAA.
Ste. Rateau.
SNECMA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
G. Dikkers and Co. N.V.
" Isola " N.V.

11 Gas circulators

AUSTRIA
Waagner-Biro AG.
BELGIUM
Ets. Neu S.A.
DENMARK
Elsinore Shipbuilding and Engineering Co., Ltd.
FRANCE
Sté. Rateau.

GERMANY
AEG.
Aerzener Maschinenfabrik GmbH.
Gutehoffnungshütte Sterkrade AG.
ITALY
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Bronswerk.
N.V. Neratoom.
SWEDEN
AB Svenska Flaktfabriken.
SWITZERLAND
Oerlikon Engineering Co.

12 Large gas valves

BELGIUM
BelgoNucléaire.
FRANCE
Ste. des Forges et Ateliers du Creusot.
MacGregor Comarain S.A.
S.A. des Ets. Neu.
Ste. Rateau.
ITALY
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
N.V. Machinenfabriek " Arnhem."
SWEDEN
AB Svenska Flaktfabriken.

13 Trace heating

BELGIUM
BelgoNucléaire.
GERMANY
Otto P. Braun.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.

14 Heat exchangers

AUSTRIA
Waagner-Biro AG.
BELGIUM
BelgoNucléaire.
Cockerill-Ougrée S.A.
Nouveaux Ateliers Lebrun.
FRANCE
Ste. Alsthom.
Compagnie des Ateliers et Forges de la Loire.
Generale Thermique.
GAAA.
SNECMA.
Ste. Lorraine-Escaut.
SOGREAH.
Ste. Stein et Roubaix.
GERMANY
Deutsche Delattre & Levivier.
Dürrwerke AG.
Gutehoffnungshütte Sterkrade AG.
Henschel-Werke GmbH.
Phoenix-Rheinrohr AG.
Pintsch Bamag AG.
Stahl- u. Rohrenwerk Reisholz GmbH.
L. and C. Steinmüller GmbH.
Vereinigte Kesselwerke AG.
Walther & Cie.
ITALY
Breda Termomeccanica.
Dalmine SpA.
Terni.
Franco Tosi SpA.
NETHERLANDS
Apparaten-en Ketelfabriek den Haag N.V.
" Aquapur."
Machinefabriek " Breda."
N.V. Bronswerk.
" Jaro."
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
Wilton-Fijenoord N.V.
NORWAY
Noratom.
SWEDEN
AB Svenska Flaktfabriken.
AB Götaverken.
Jonkopings Mek. Verkstads/AB.
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.
The Sandvik Steelworks Co., Ltd.
Uddeholms AB.

15 Absolute shaft seals

FRANCE
SNECMA.

G REACTOR CONTROL EQUIPMENT

1 Power and flux measuring

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Ste. Alsacienne de Constructions Mecaniques.
Cie Industrielle des Combustibles Atomiques Frittes.
Commission de l'Instrumentation Nucléaire Française.
CSF.
GAAA.
Compagnie Française Thomson-Houston.
GERMANY
AEG.
Graetz-Raytonik GmbH.
Hartmann and Braun AG.
Dr. Virus Kerntechnik GmbH.
ITALY
Fiat.
NETHERLANDS
N.V. Neratoom.
N.V. Philips' Gloeilampenfabrieken.
NORWAY
Noratom.

2 Flux scanning

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Ste. Alsacienne de Constructions Mecaniques.
Commission de l'Instrumentation Nucléaire Française.
GAAA.
GERMANY
AEG.
Hartmann and Braun AG.
Dr. Virus Kerntechnik GmbH.
ITALY
SELO.

3 Thermocouples

FRANCE
Ste. Alsacienne de Constructions Mecaniques.
Commission de l'Instrumentation Nucléaire Française.
GAAA.
La Radiotechnique.
Siersatom.
SODERN.
GERMANY
Hartmann and Braun AG.
AEG.
Otto P. Braun.
NETHERLANDS
N.V. Neratoom.
N.V. Philips' Gloeilampenfabrieken.

4 Other physical inst.

BELGIUM
MBLE.
FRANCE
Commission de l'Instrumentation Nucléaire Française.
CSF.
Ets. Merlin et Gerin.
SFIM.
Siersatom.
SODERN.
SOM.
Compagnie Française Thomson-Houston.
GERMANY
AEG.
Hartmann and Braun AG.
Albert Knott.
Dr. Virus Kerntechnik GmbH.
ITALY
Magrini SpA.
NETHERLANDS
Fischer and Porter.
W. C. 'tHart and Zn.
N.V. Neratoom NIEAF.
N.V. Philips' Gloeilampenfabrieken.

5 Burst fuel element detection

FRANCE
Ste. Alsacienne de Constructions Mecaniques.
COCEI.
Commission de l'Instrumentation Nucléaire Française.
L'Electronique Appliquée.
GAAA.
Intertechnique.
Ste. Lorraine-Escaut.
Ste. Rateau.
GERMANY
AEG.
F. J. Gattys Ingenieurbüro.

6 Control rods

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Commission de l'Instrumentation Nucléaire Française.
CSF.
GAAA.
Ste. Lorraine-Escaut.
" Metafram."
GERMANY
AEG.
Rochling'sche Eisen- u. Stahlwerke GmbH.
Dr. Virus Kerntechnik GmbH.
Siemens Schuckertwerke AG.
NORWAY
Kongsberg Väpenfabrikk.
Noratom.
SWITZERLAND
AMF Atomics.
Secheron Works Co. Ltd.

7 Control rod drives

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Commission de l'Instrumentation Nucléaire Française.
CSF.
Ste. des Forges et Ateliers du Creusot.
GAAA.
Ste. Lorraine-Escaut.
Forges et Chantiers de la Mediterranée.
GERMANY
AEG.
Hartmann and Braun AG.
Siemens Schuckertwerke AG.
NORWAY
Kongsberg Väpenfabrikk.
Noratom.
SWITZERLAND
AMF Atomics.
Oerlikon Engineering Company.

8 In-pile inspection

FRANCE
Commission de l'Instrumentation Nucléaire Française.
GAAA.
SOM.
Compagnie Française Thomson-Houston.
GERMANY
AEG.

9 Control panels

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Ste. Alsacienne de Constructions Mecaniques.
Ste. Alsthom.
Commission de l'Instrumentation Nucléaire Française.
CSF.
Ste. L'Electro-Entreprise.
GAAA.
Compagnie Française Thomson-Houston.
GERMANY
AEG.
Hartmann and Braun AG.
Siemens Schuckertwerke AG.
NETHERLANDS
" Aquapur."
Machinefabriek " Breda."
Fischer and Porter.
N.V. Neratoom.
N.V. Philips' Gloeilampenfabrieken.
NORWAY
Noratom.

H ANCILLARIES

1 Refuelling machinery

AUSTRIA
Waagner-Biro AG.
BELGIUM
ACEC.
BelgoNucléaire.
Nouveaux Ateliers Lebrun.
DENMARK
Thomas B. Thrige.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
GERMANY
Deutsche Delattre and Levivier.
NORWAY
Noratom.
SWEDEN
Nydqvist and Holm AB.
SWITZERLAND
Ateliers des Charmilles.
AMF Atomics.
Sécheron Works.

2 Coolant storage

AUSTRIA
Waagner-Biro AG.
BELGIUM
BelgoNucléaire.
Cockerill-Ougrée S.A.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Stein et Roubaix.
GERMANY
Donges Stahlbau.
Pintsch Bamag AG.
Deutsche Delattre & Levivier.
NETHERLANDS
" Aquapur."
Apparaten-en Ketelfabriek.
N.V. Leidsche Apparatenfabriek.
N.V. Neratoom.
NORWAY
Noratom.

3 Ventilation plant

AUSTRIA
Waagner-Biro AG.
BELGIUM
Belchim.
BelgoNucléaire.
Ets. Neu S.A.
FRANCE
S.A. des Ets. Neu.
Ste. Rateau.
Saint-Gobain Nucléaire.

NETHERLANDS
Apparaten-en Ketelfabriek.
N.V. Bronswerk.
Pielkenrood-Vinitex.
NORWAY
Noratom.
Theodor Qviller.
SWEDEN
AB Svenska Flaktfabriken.

4 Filtration units

BELGIUM
Belchim.
Ets. Neu S.A.
FRANCE
Degremont.
L'Electronique Appliquée.
" Metafram."
S.A. des Ets. Neu.
Saint-Gobain Nucléaire.
Ste. de Recherches et d'Applications Techniques.
Stein et Roubaix.
Ugine.
GERMANY
Auergesellschaft GmbH.
Walter Boll Filter GmbH.
Berkefeld-Filter GmbH.
CEAG.
Dragerwerk.
Pintsch Bamag AG.
NETHERLANDS
" Aquapur."
Apparaten-en Ketelfabriek.
Duper Water Cond. Co.
N.V. Leidsche Apparatenfabriek.
AB Svenska Flaktfabriken.
NORWAY
Noratom.
Theodor Qviller.

5 Demineralization

BELGIUM
Ste. d'Arendonk.
Belchim.
FRANCE
Degremont.
SOGREAH.
Stein et Roubaix.
GERMANY
Berkefeld-Filter GmbH.
Farbenfabriken Bayer AG.
Pintsch Bamag AG.
Steinmuller.
ITALY
Termomeccanica Italiana.
NETHERLANDS
" Aquapur."
Duper Water Cond. Co.
Imacti Industrieele.
N.V. Leidsche Apparatenfabriek.

6 Effluent treatment

AUSTRIA
Waagner-Biro AG.
BELGIUM
Belchim.
FRANCE
Degremont.
Saint-Gobain Nucléaire.
Siersatom.
SOGREAH.
Stein et Roubaix.
GERMANY
Berkefeld-Filter GmbH.
Farbenfabriken Bayer AG.
Pintsch Bamag AG.
Steinmuller.
ITALY
Termomeccanica Italiana.
NETHERLANDS
" Aquapur."
Nucleaire Service Mij.
NORWAY
Noratom.
SWITZERLAND
AMF Atomics.

7 Waste disposal

BELGIUM
ACEC.
Ste. d'Arendonk.
Belchim.
FRANCE
Saint-Gobain Nucléaire.
GERMANY
Deutsche Delattre & Levivier.
Farbenfabriken Bayer AG.
Pintsch Bamag AG.
NETHERLANDS
" Aquapur."
Apparaten-en Ketelfabriek.
Van Leer's Vatenfabrieken.
Nucleaire Service Mij.
NORWAY
Noratom.
SWITZERLAND
AMF Atomics.

J PROCESSING

1 U/Th purification

BELGIUM
Belchim.
Ste. Générale Métallurgique de Hoboken.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Degremont.
Ets. Kuhlmann.
SOGREAH.
GERMANY
NUKEM.

2 Metal fuel production

BELGIUM
Ste. Générale Métallurgique de Hoboken.
FRANCE
Saint-Gobain Nucléaire.
GERMANY
NUKEM.

3 Oxide, carbide production

AUSTRIA
Metallwerk Plansee AG.
BELGIUM
BelgoNucléaire.
Ste. Générale Métallurgique de Hoboken.
FRANCE
CSF.
Ets. Kuhlmann.
Pechiney.
Saint-Gobain Nucléaire.
Ugine.
GERMANY
Th. Goldschmidt AG.
NUKEM.

4 Irradiated element treatment

BELGIUM
Belchim.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Degremont.
Saint-Gobain Nucléaire.
NORWAY
Noratom.

K MATERIALS

1 Be metal alloys

FRANCE
Pechiney.

2 Al nuclear grade

FRANCE
Pechiney.
Trefileries et Laminoirs du Havre.
Ugine.
GERMANY
Metallgesellschaft AG.
NORWAY
Noratom.

3 S A P

FRANCE
Pechiney.
Trefileries et Laminoirs du Havre.

4 Mg alloys

FRANCE
Trefileries et Laminoirs du Havre.
Ugine.
GERMANY
Metallgesellschaft AG.

5 Zr, Zr alloys

FRANCE
CSF.
Pechiney.
Trefileries et Laminoirs du Havre.
Ugine.
SWEDEN
The Sandvik Steelworks Co., Ltd.
SWITZERLAND
Demierre et Cie S.A.

6 B metal alloys

FRANCE
Ets. Kuhlmann.
Pechiney
GERMANY
Rochling'sche Eisen- u. Stahlwerke GmbH.

7 Rare earths

FRANCE
Pechiney.
GERMANY
Frank & Schulte Handels GmbH.

8 Graphite, nuclear grade

FRANCE
Pechiney.
Ugine.
GERMANY
Kropfmuhl-Ringsdorff AG.
Sigri-Kohlefabrikate.

9 Graphite, impregnated

FRANCE
Pechiney.
GERMANY
Sigri-Kohlefabrikate.

10 Heavy water

GERMANY
Farbwerke Hoechst AG.
NORWAY
Noratom.

11 Gaseous coolants

FRANCE
Ugine.

12 Organic coolants

FRANCE
Ugine.
GERMANY
Farbenfabriken Bayer AG.

13 Liquid metals

FRANCE
Ets. Kuhlmann.
Ugine.

14 Steel for reactor vessels

BELGIUM
BelgoNucléaire.
Cockerill-Ougrée S.A.
S.A. Usines Emile Henricot.
FRANCE
Compagnie des Ateliers et Forges de la Loire.
Ste. des Forges et Ateliers du Creusot.
Ste. Lorraine-Escaut.
GERMANY
Donges Stahlban.
Kloeckner-Werke AG.
Phoenix-Rheinrohr AG.
Rochling'sche Eisen- u. Stahlwerke GmbH.
Stahl- u. Rohrenwerk Reisholz GmbH.
ITALY
Terni.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.
Uddeholms.

15 Lead

BELGIUM
Ste. des Mines et Fonderies de Zinc de la Vieille Montagne S.A.
GERMANY
Metallgesellschaft AG.
Stolberger Zink AG.
Vereinigte Bleiwerke GmbH.
NETHERLANDS
Zuid-Hollandsche Pletterijen.
NORWAY
Noratom.
SWEDEN
Rederiaktiebolaget Nordstjernan Atomkraftgruppen.

16 Radiation resist. lubricants

BELGIUM
BelgoNucléaire.
GERMANY
Vereinigte Bleiwerke GmbH.

L ACTIVE HANDLING

1 Hot caves

AUSTRIA
Waagner-Biro
BELGIUM
Belchim.
BelgoNucléaire.
FRANCE
GAAA.
St. Gobain Nucléaire.
Donges Stahlbau.
GERMANY
IGK.
Hans Walischmiller.
ITALY
Fiat.
NORWAY
Noratom.

2 Glove boxes

BELGIUM
Belchim.
BelgoNucléaire.
GERMANY
F. J. Gattys Ingenieurbüro.
Hans Walischmiller.
FRANCE
St. Gobain Nucléaire.
Siersatom.
Ugine.
ITALY
Carem.
Fiat.
NORWAY
Noratom.
NETHERLANDS
Nucleaire Service.
Philips-Duphar.

3 Shielding bricks

BELGIUM
Belchim.
Ste. des Mines et Fonderies de Zinc de la Vieille Montagne.
D'Overpel-Lommel.
FRANCE
CSF.
St. Gobain Nucléaire.
GERMANY
Buchler.
Frank & Schulte Handelgesellschaft.
Grun & Bilfinger.
Poetschke.
Vereinigte Bleiwerke.
Wayss & Freytag.
Hans Walischmiller.
Dr. Virus Kerntechnik.
NETHERLANDS
Mij Ago N.V.
Philips-Duphar.
RTD N.V.
Zuid-Hollandsche Pletterijen.
NORWAY
Noratom.

4 Windows

BELGIUM
Belchim.
Ste. des Mines et Fonderies de Zinc de la Vieille Montagne.
GERMANY
Buchler.
F. J. Gattys Ingenieurbüro.
Jenaer Glaswerk.
Vereinigte Bleiwerke.
E. Merck.
Hans Walischmiller.

FRANCE
St. Gobain Nucléaire.
ITALY
Fiat.
NORWAY
Noratom.
Zuid-Hollandsche Pletterijen.

5 Lead spheres
BELGIUM
Belchim.
GERMANY
Frieseke & Hoepfner.
Hans Walischmiller.
ITALY
Gilardoni.
NETHERLANDS
RTD N.V.
Zuid-Hollandsche Pletterijen.

6 Tongs
BELGIUM
Belchim.
FRANCE
Gamma Industrie.
St. Gobain Nucléaire.
GERMANY
Buchler.
P. Vogel.
Hans Walischmiller.
SWITZERLAND
P. Vogel.

7 Master slave manipulators
BELGIUM
Belchim.
FRANCE
GAAA.
SOM.
St. Gobain Nucléaire.
Siersatom.
GERMANY
Hans Walischmiller.
SWITZERLAND
AMF Atomics.

8 Remote controlled
FRANCE
GAAA.
SOM.
St. Gobain Nucléaire.
Siersatom.
GERMANY
Buchler.
Hans Walischmiller.
SWITZERLAND
AMF Atomics.
Ateliers des Charmilles.
Mettler.

9 Protective clothing
FRANCE
St. Gobain Nucléaire.
GERMANY
Auergesellschaft.
Drægerwerk.
Hans Walischmiller.
Poetschke.

10 Protective finishes
BELGIUM
Phenix Works.
GERMANY
Hans Walischmiller.
ITALY
Imper.
NETHERLANDS
Nucléaire Service.
Vettewinkel.

11 Viewing instruments
FRANCE
Ets. J. Bodson.
SOM
St. Gobain Nucléaire.
GERMANY
Hans Walischmiller.
NORWAY
Noratom.
SWITZERLAND
Demierre.

12 Remote controlled machine tools
BELGIUM
Belchim.
FRANCE
GAAA.
St. Gobain Nucléaire.
Siersatom.
GERMANY
Buchler.
Donges Stahlbau.
Hans Walischmiller.
NORWAY
Noratom.

13 Transport flasks
AUSTRIA
Waagner-Biro.
BELGIUM
Belchim.
Phenix Works.
DENMARK
Elsinore Shipbuilding and Engineering.
A/S Frichs.
FRANCE
GAAA.
St. Gobain Nucléaire.
GERMANY
Deutsche Delattre & Levivier.
Donges Stahlbau.
F. J. Gattys Ingenieurbüro.
Henschel-Werke GmbH.
Vereinigte Bleiwerke GmbH.
Dr. Virus Kerntechnik.
Hans Walischmiller.
NORWAY
Noratom.
NETHERLANDS
Apparaten-en Ketelfabriek.
Nucléaire Service.
Wilton-Fijenoord N.V.
ITALY
Gilardoni.
SWITZERLAND
P. Vogel.

M RESEARCH

1 Accelerators
BELGIUM
ACEC.
BelgoNucléaire.
DENMARK
Thomas B. Thrige.
FRANCE
Ste. Alsthom.
Compagnie des Ateliers et Forges de la Loire.
Inst. Nucléaire Française.
CSF.
Ste. des Forges et Ateliers du Creusot.
Gamma Industrie.
SAMES.
GERMANY
AEG.
Siemens-Schuckertwerke AG.
Dr. Virus Kerntechnik.
NETHERLANDS
N.V. Neratoom.
N.V. Philips.
SWITZERLAND
Oerlikon Engineering Co.

2 Neutron generators
BELGIUM
BelgoNucléaire.
FRANCE
CSF.
SAMES.
GERMANY
AEG.
Elektrophysik Dr. Stephan.
Hartmann & Braun AG.
Siemens-Schuckertwerke AG.
Dr. Virus Kerntechnik.
NETHERLANDS
Koopman & Co.
N.V. Neratoom.
N.V. Philips.

3 Sub-critical assemblies
BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
GAAA.
SAMES.
GERMANY
AEG.
Siemens-Schuckertwerke AG.
Dr. Virus Kerntechnik.
NORWAY
Noratom.

4 Neutron spectrometers
BELGIUM
ACEC.
FRANCE
Instr. Nucléaire Française.
L'Electronique Appliquée.
GERMANY
Reichert-Elektronik.
Laben.
NORWAY
Noratom.

5 Computers
BELGIUM
BelgoNucléaire.
FRANCE
ANALAC.
Instr. Nucléaire Française.
Compagnie Européenne d'Automatisme Electronique.
CSF.
GAAA.
SACM.
GERMANY
Hartmann & Braun AG.
Albert Knott.
Poetschke.
Reichert-Elektronik.
Dr. Virus Kerntechnik.

6 Data processing
BELGIUM
BelgoNucléaire.
Bell Telephone Mfg. Co.
FRANCE
Instr. Nucléaire Française.
Compagnie Européenne d'Automatisme Electronique.
CSF.
GAAA.
SACM.
GERMANY
AEG.
Fernsteuergeräte.
Hartmann and Braun AG.
NETHERLANDS
N.V. Neratoom.
N.V. Philips.
NORWAY
Noratom.

7 Reactor simulators
BELGIUM
Bell Telephone Mfg. Co.
FRANCE
Compagnie Européenne d'Automatisme Electronique.
Instr. Nucléaire Française.
CSF.
GERMANY
AEG.
NETHERLANDS
Apparaten-en Ketelfabriek.
N.V. Neratoom.

8 In-pile loops
BELGIUM
BelgoNucléaire.
SERAI.
FRANCE
L'Electronique Appliquée.
GAAA.
Ste. Rateau.
SNECMA.
SOGREAH.
TBT.
GERMANY
Sieimens-Schuckertwerke AG.
NETHERLANDS
Apparaten-en Ketelfabriek.
De Rotterdamsche Droogdok Mij.
NORWAY
Noratom.
SWITZERLAND
AMF Atomics.

9 Out-of-pile rigs
BELGIAN
SERAI.
FRANCE
Ste. Alsthom.
Ste. Rateau.
SOGREAH.
GERMANY
Siemens-Schuckertwerke AG.
NETHERLANDS
De Rotterdamsche Droogdok Mij.
NORWAY
Noratom.

10 Special instruments
BELGIUM
ACEC.
BelgoNucléaire.
Bell Telephone Mfg. Co.
MBLE.
FRANCE
Instr. Nucléaire Française.
CSF.
L'Electronique Appliquée.
Jeumont.
Lie Belin.
Optique et Precision de Levallois.
SNECMA.
Ste. d'Etudes de Constructions et d'Equipments.
Siersatom.
SOM.
Compagnie Française Thomson-Houston.
GERMANY
Hartmann and Braun AG.
E. Leitz GmbH.
Steinheil Sohne.
ITALY
Fratelli Koriska SpA.
Laben.
SELO.
NETHERLANDS
Apparaten-en Ketelfabriek.
N.V. Neratoom.
N.V. Philips.
NORWAY
Noratom.
SWITZERLAND
Mettler.

11 Special machines
BELGIUM
ACEC.
BelgoNucléaire.
Nouveaux Ateliers Lebrun.
DENMARK
Thomas B. Thrige.
FRANCE
Ste. Alsthom.
Bonnet-Calad S.A.
Instr. Nucléaire Française.
CSF.
Ste. des Forges et Ateliers du Creusot.
GAAA.
Jeumont.
Rateau.
SECE.
SNECMA
Siersatom.
VMDI.

GERMANY
AEG
F. J. Gattys Ingenieurbüro.
NETHERLANDS
Apparaten-en Ketelfabriek.
N.V. Neratoom.
NORWAY
Noratom.
SWITZERLAND
Oerlikon Engineering Co.

N INSTRUMENTATION

1 Laboratory nucleonic

BELGIUM
ACEC.
BelgoNucléaire.
Bell Telephone.
MBLE.
FRANCE
CERE.
CRC.
Ets. J. Bodson.
Inst. Nuc. Française.
CSF.
L'Electronique Appliquée.
GAAA.
Siersatom.
SRAT.
Française Thomson-Houston.
GERMANY
Elektrophysik Dr. Stephan.
Frieseke & Hoepfner.
Hartmann & Braun.
Herfurth.
Albert Knott.
Laboratorium Berthold.
Poetschke.
Telefunken.
Dr. Virus Kerntechnik.
ITALY
Laben.
SELO.
NETHERLANDS
Baird-Atomic (Holland).
Neratoom.
Philips.
NORWAY
Noratom.

2 Health monitors

BELGIUM
ACEC.
BelgoNucléaire.
Bell Telephone.
MBLE.
FRANCE
CERE.
CRC.
CSF.
Inst. Nuc. Française.
L'Electronique Appliquée.
GAAA.
SRAT.
GERMANY
Elektrophysik Dr. Stephan.
Frieseke & Hoepfner.
Hartmann & Braun.
Herfurth.
Albert Knott.
Laboratorium Berthold.
Physikalisch-Tech. Pychlau.
Poetschke.
Reichert-Elektronik.
Strahlenschutz.
Dr. Virus Kerntechnik.
ITALY
SELO.
NETHERLANDS
Baird-Atomic (Holland).
Neratoom.
Philips.
NORWAY
Noratom.
Standard Telefon.

3 Survey meters

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
CERE.
CSF.
Inst. Nuc. Française.
L'Electronique Appliquée.
LIE Belin.
SFIM.
SRAT.
GERMANY
Elektrophysik Dr. Stephan.
Versuchaanlage für Uranerzverarbeitung der Gewerkschaft Brunhilde.
Frieseke & Hoepfner.
Hartmann & Braun.
Albert Knott.
Laboratorium Berthold.
Physikalisch-Tech. Pychlau.
Poetschke.
Reichert-Elektronik.
Telefunken.
Dr. Virus Kerntechnik.
ITALY
SELO.
NETHERLANDS
Neratoom.
Philips.
NORWAY
Standard Telefon.

4 G-M tubes etc.

BELGIUM
ACEC.
BelgoNucléaire.
Bell Telephone.
FRANCE
CERE.
CSF.
Inst. Nuc. Française.
La Physiotechnie.
La Radiotechnique.
SRAT.
GERMANY
AEG.
Elektrophysik Dr. Stephan.
Frieske & Hoepfner.
Hartmann & Braun.
Albert Knott.
Laboratorium Berthold.
Poetschke.
Dr. Virus Kerntechnik.
ITALY
SELO.
NETHERLANDS
Neratoom.
Philips.

5 Ion chambers

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Ets. Beaudouin.
CSF.
Inst. Nuc. Française.
GAAA.
La Physiotechnie.
La Radiotechnique.
Ets. Merlin and Gerin.
SRAT.
GERMANY
AEG.
Elektrophysik Dr. Stephan.
Frieseke & Hoepfner.
Hartmann & Braun.
Albert Knott.
Poetschke.
Reichert-Elektronik.
Dr. Virus Kerntechnik.
ITALY
SELO.
NETHERLANDS
Neratoom.
Philips.

6 Scintillators

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Inst. Nuc. Française.
Quartz & Silice.
La Radiotechnique.
SRAT.
GERMANY
Elektrophysik Dr. Stephan.
Frieseke & Hoepfner.
Hartmann & Braun.
Albert Knott.
E. Merck.
Poetschke.
Reichert-Elektronik.
Dr. Virus Kerntechnik.
NETHERLANDS
Neratoom.
Philips.

7 Scintillation counters

BELGIUM
ACEC.
BelgoNucléaire.
Bell Telephone.
MBLE.
FRANCE
CSF.
Inst. Nuc. Française.
L'Electronique Appliquée.
LIE Belin.
SRAT.
GERMANY
Elektrophysik Dr. Stephan.
Frieseke & Hoepfner.
Hartmann & Braun.
Albert Knott.
Laboratorium Berthold.
Poetschke.
Reichert-Elektronik.
Telefunken.
Dr. Virus Kerntechnik.
ITALY
SELO.
NETHERLANDS
Baird-Atomic (Holland).
Neratoom.
Philips.

8 Non-destructive testing

BELGIUM
ACEC.
BelgoNucléaire.
FRANCE
Ets. Beaudouin.
Inst. Nuc. Française.
Gamma Industrie.
SNECMA.
GERMANY
Frieske & Hoepfner.
Phoenix-Rheinrohr AG.
Dr. Virus Kerntechnik.
Walther & Cie.
ITALY
Gilardoni.
NETHERLANDS
Branson Europa.
Neratoom.
Philips.
RTD N.V.

9 Gas analysis

FRANCE
CSF.
Inst. Nuc. Française.
Ugine.
GERMANY
Atlas-Werke.
Frieseke & Hoepfner.
Hartmann & Braun.
Poetschke.
Dr. Virus Kerntechnik.

10 General laboratory

BELGIUM
BelgoNucléaire.
FRANCE
CRC.
CSF.
Inst. Nuc. Française.
L'Electronique Appliquée.
Siersatom.
SNECMA.
Française Thomson-Houston.
GERMANY
Elektrophysik Dr. Stephan.
Hartmann & Braun.
Albert Knott.
Dr. Bruno Lange.
Reichert-Elektronik.
Steinheil Sohne.
Telefunken.
Dr. Virus Kerntechnik.
NETHERLANDS
NIEAF.
Philips.
Pielkenrood-Vinitex.

P ISOTOPES

1 Labelled compounds

BELGIUM
BelgoNucléaire.
FRANCE
SRTI.
GERMANY
Farbwerke Hoechst AG.
Dr. Virus Kerntechnik.
NETHERLANDS
Neratoom.
Philips.
Philips-Duphar.
NORWAY
Noratom.

2 Industrial applications

BELGIUM
BelgoNucléaire.
Bell Telephone.
FRANCE
Inst. Nuc. Française.
CSF.
L'Electronique Appliquée.
Gamma Industrie.
SRTI.
GERMANY
Farbwerke Hoechst.
Interatom.
Nuclear GmbH.
Dr. Virus Kerntechnik.
ITALY
Gilardoni.
NETHERLANDS
Koopman.
Neratoom.
Philips.
Philips-Duphar.
RTD.
NORWAY
Noratom.
SWEDEN
AB Atomenergi.

3 Irradiation facilities

BELGIUM
BelgoNucléaire.
FRANCE
St. Gobain-Nucléaire.
SRTI.
TBT.
GERMANY
Nuclear.
NETHERLANDS
Koopman.
Philips.
Philips-Duphar
SWEDEN
AB Atomenergi.